Repco AUTO TECH

AUTO-TECH MASTERCLASS

Training for Master Technicians

2018.3

Cooling Systems

The Evolution of Thermal Management Systems

Correct Coolant Applications – Coloured to confuse

Overheating Diagnostics with Scan tool, thermocouples & thermal imaging

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Climate Control Systems

Refrigerant Charging – the right pressure for optimal cooling

Variable Displacement Compressors – Diagnostics & Design

R134A / R1234YF Changes & CO_2 A/C systems

ENGINE COOLING & CLIMATE CONTROL

Section i

Cooling Systems

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INTRODUCTION

Liquid cooling systems have been around since the first production cars hit our roads and the technology used in the these systems has evolved slowly and steadily since that time. That was until Australia properly joined the global shift to lowering vehicle emissions in 2005. We have now seen a raft of technologies being employed to lower emissions and the cooling system is key to many of these technologies.

The original purpose of the cooling system for the Internal Combustion Engine (ICE) was to remove the unwanted heat from the engine that would cause premature failure of components.

As engine output increased so did the demand on the cooling system. The modern engine still needs to dissipate excessive heat, but how much heat and when has become a very technical process. Heat is not always a bad thing!

In 2018, a cooling system is more accurately described as a Thermal Management System. This is because it is used to balance the warm up timing between the Engine, Turbocharger, Heater Core and Transmission. Once the engine and its components have reached normal operating temperature the Thermal Management System then starts to control the operating temperature by cooling.

In an ICE, fuel and air are ignited and converted into heat energy. Roughly 1/3 of that heat energy causes expansion driving down the piston another 1/3 is expelled out the exhaust with the remaining 1/3 absorbed into the metal components of the engine where it is transferred to the atmosphere via the Radiator.

By increasing the temperature at which the engine is regulated, less heat energy from the combustion is wasted and this results in improved fuel economy. Unfortunately it is not possible to always run the engine at higher temperatures because pre-ignition or knocking will occur which has the reverse effect.

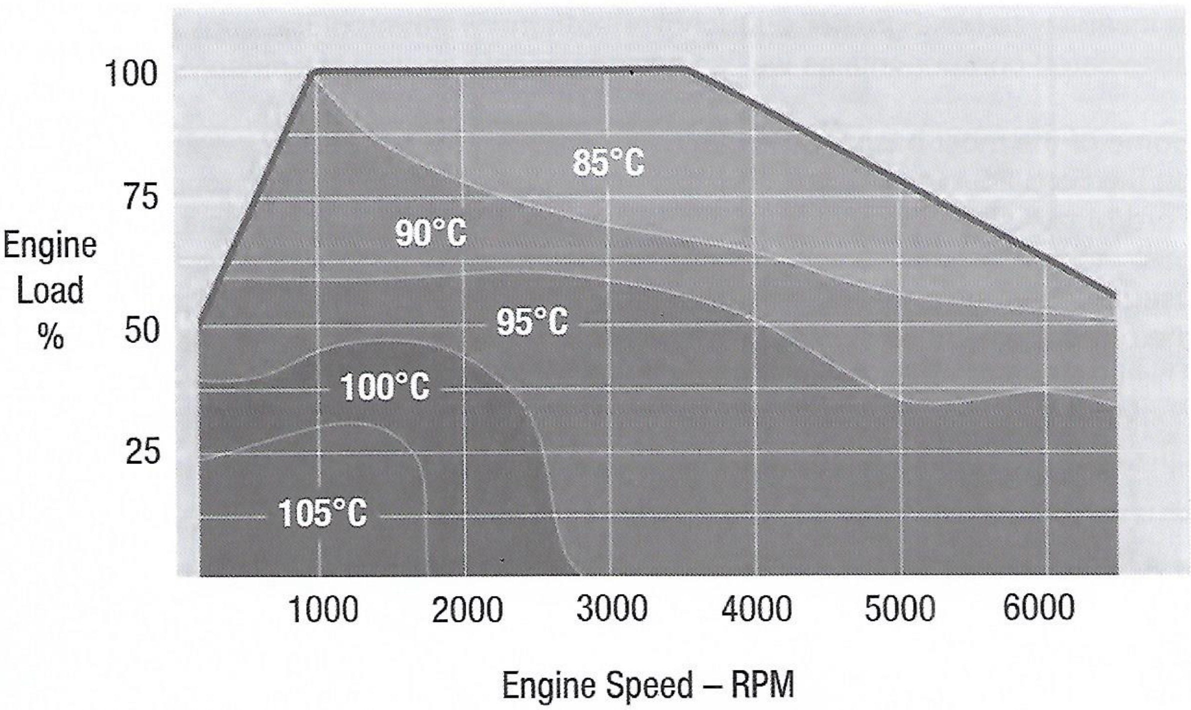
The answer to this is to lower the engines operating temperature under high load conditions (when engine knock is most likely) and increase the temperature during low load cruise conditions where the highest benefit from fuel economy can be achieved.

So, what is the best operating temperature for an ICE?

The short answer: As hot as possible...

The not so short answer:
H^2O is a by-product of combustion, when all engine components are above 100°C the water remains gaseous and does not condense, therefore it is expelled from the vehicle via the exhaust system. Most petrol vehicles running a TMS have the low load operating temperature set around 105-107°C and a full load operating temperature set around 85°C.

INTRODUCTION continued...



① modern engs run @ Approx 105°C

② Higher Temps keep water By Product as a gas to stop oil sluding

③ 85°C under load is what the modern eng is trying achieve-

* This Temp is Important in Diagnosing

④ Scan Tool is Primary Tool for Diag on modern engs.

Note:

In January 2018, The Australian Government released its draft Regulation Impact Statement (RIS) into vehicle emissions and minimum fuel quality. All Vehicle Manufacturer's support Option B which is to meet the European Standard with a minimum of 95RON, lower sulphur to 10ppm and limit aromatic content to 35%. The Australian Petroleum Industry is supporting Option F which is to only lower the sulphur content.

Higher RON allows for increased engine operating temperatures.

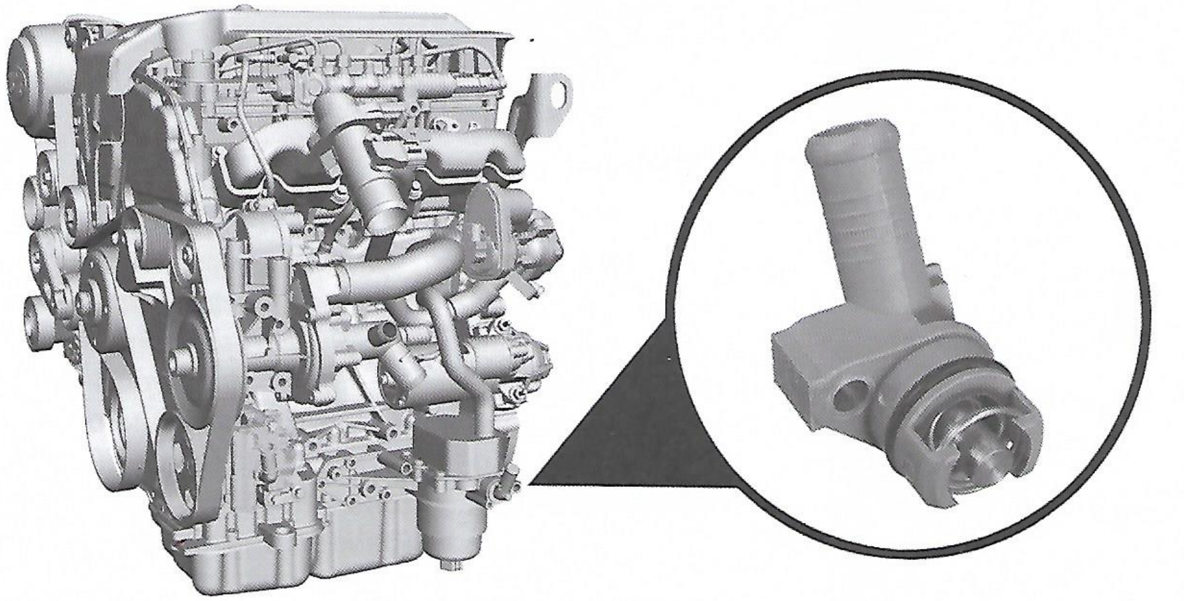
Manufacturers including Toyota Australia and Mercedes Benz (on behalf of many European car manufacturers) have responded by saying that they will not bring EURO 6c or 6d compliant vehicles into Australia until Option B is implemented!

Changes are scheduled to be passed in 2019 with a 2022 implementation.

THERMAL MANAGEMENT SYSTEMS

A Thermal Management System (TMS) differs from a cooling system primarily in its ability to have greater control over both the warming of the engine and it's associated components as well as having variable cooling rates.

Some of the most basic TMS have two thermostats. These are especially common on the Ford/PSA joint-developed "Duratorq-Puma" diesel engines found in many Ford/Mazda/JLR/Volvo/Peugeot/Citroen models from 2000 onwards. Unknown to many technicians is a small secondary thermostat located in the oil cooler which is used to open the coolant flow through the oil cooler when the temperature within the oil cooler reaches about 75°C (actual temperature varies slightly across models). This is especially important because if the cooling system is running too cool the oil cooler is deactivated to prevent over cooling of the oil which can have catastrophic effect for the Engine but more so for the Turbocharger.



Oil Cooler Thermostat as found on 2.4L Land Rover Defender from 2007-2012

It is necessary to remove this thermostat during draining and flushing of the cooling system so that the old coolant is flushed out of the oil cooler circuit. While this has been an example of the most commonly found system of this type, similar procedures apply to many other vehicles. Don't assume that a system can be drained and flushed simply by removing the bottom radiator hose and the thermostat.

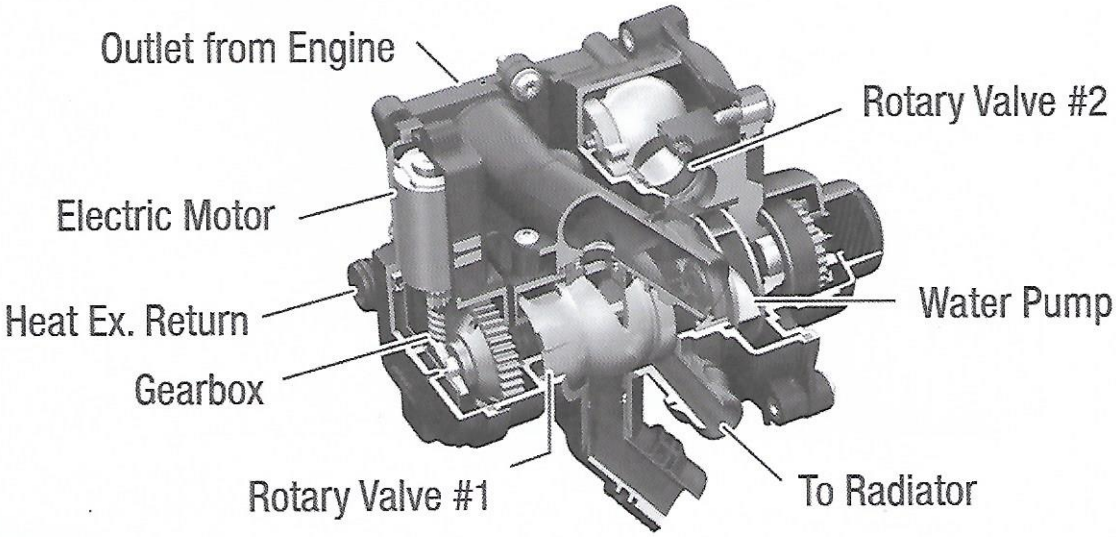
⚠ *Caution:* *Many vehicles have specific draining, flushing and filling requirements. The manufacturers procedure should always be reviewed before servicing!*

THERMAL MANAGEMENT SYSTEMS continued...

More complex TMS have electronic control over the temperature and/or flow of the coolant. This includes Electronic Thermostats, Electronic Water Pumps and Thermal Management Modules.

Thermal Management Module (TMM)

The TMM was designed and manufactured by Schaeffler and is currently being used on Audi and VW models fitted with an EA888 Gen3 engine. The TMM incorporates the water pump and two electronically driven rotary valves that replace the thermostat. The TMM is located on the left/front side of the cylinder block where the water pump is driven off the back (flywheel end) of the balance shaft by a small toothed belt. The finned pulley on the water pump draws air through the vented housing to prevent the pulley and belt from overheating.



Schaeffler Thermal Management Module

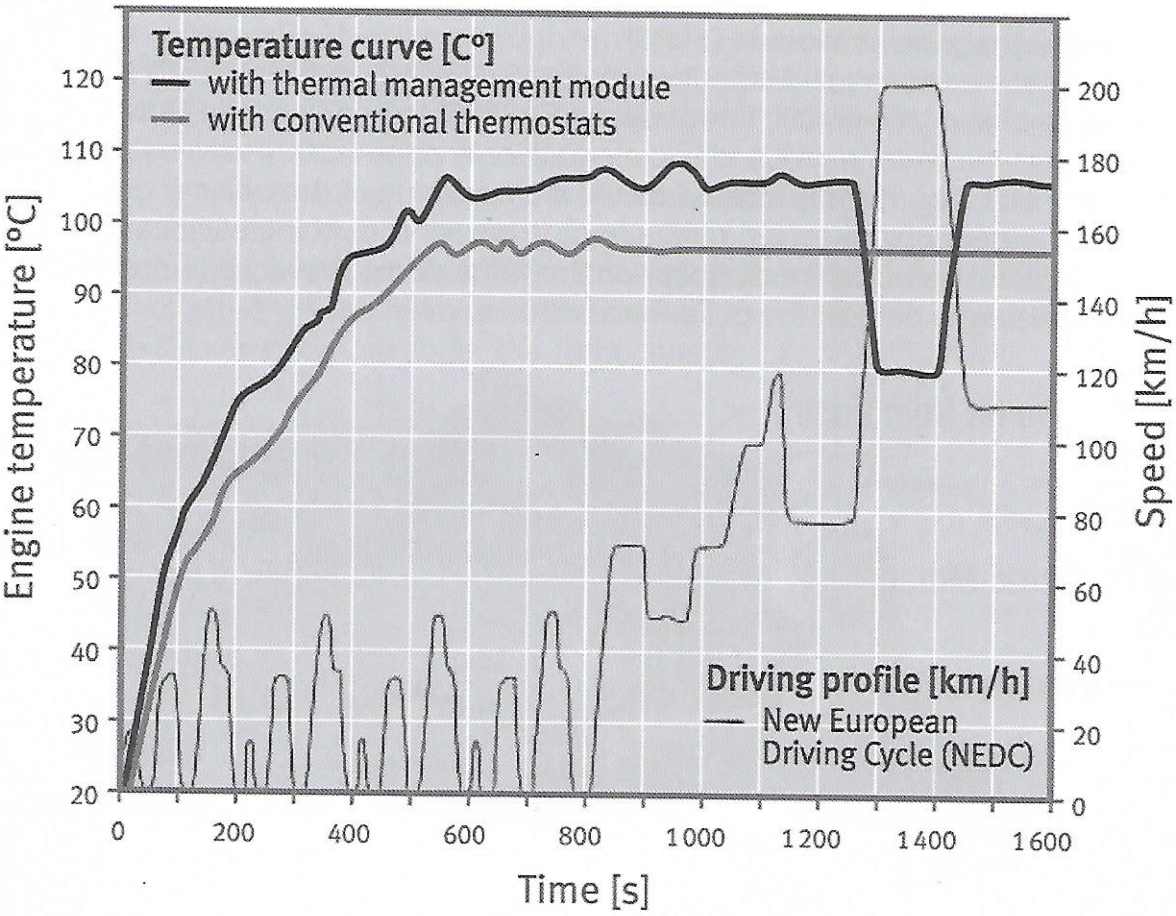
The Engine ECU controls the two rotary valves via the electric motor, providing 8 different coolant control strategies:

- Cold Start – No Flow at all
- Aux. Heating – Cylinder Head, Turbo & HVAC
- Partial cooling
- Engine Oil cooling
- Transmission Oil cooling
- Low load cooling – 107°C
- Full load cooling – 85°C
- Turbocharger cool down – After engine shutdown

① Sub Pump only works when Temp above 85°C & Key is off
*Test. only when Key is off & Temp above 85°C
② Works similier to a Turbo Timer to protect Turbo.

THERMAL MANAGEMENT SYSTEMS continued...

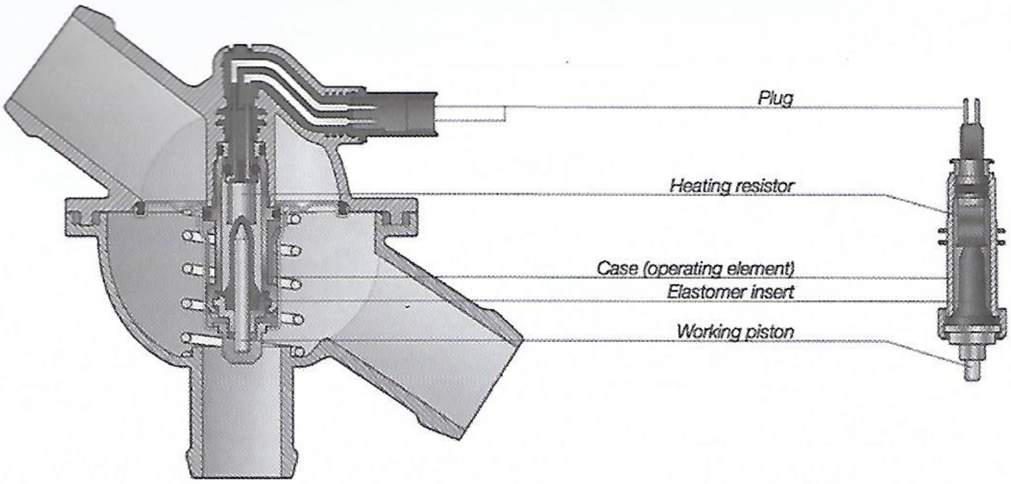
The following chart shows a comparison between the running temperature of an engine using a TMM against that of a vehicle using a traditional thermostat.



THERMAL MANAGEMENT SYSTEMS continued...

Electronic Thermostats

The functioning (moving) component of the thermostat is largely unchanged and still operates under the control of the thermostatic wax element. The only functional difference is that an electric heating element is located inside the element to allow the thermostat to be controlled by both coolant temperature and electronic control from the ECM. Electronic Thermostats are integrated into the water outlet housing in order to provide a sealed electrical connection port that is easily serviced.



Electronic Thermostat operation

All Electronic Thermostats work to approximately the same parameters:

Full operating range:	Approximately 80°C to 110°C
Thermostatic Wax Element:	Set to open at upper threshold (eg. 110°C)
Electric Element:	Lowers the opening temperature, Duty Cycle control allows variation. 100% Duty Cycle will reduce opening temperature to lower threshold (eg. 80°C)

3 Fault that are Comon

① Thermostat control high ie- high voltage Drop means not open circuit problem is a short.

- [redacted]
- low voltage Drop means an open circuit in wiring or circuit.

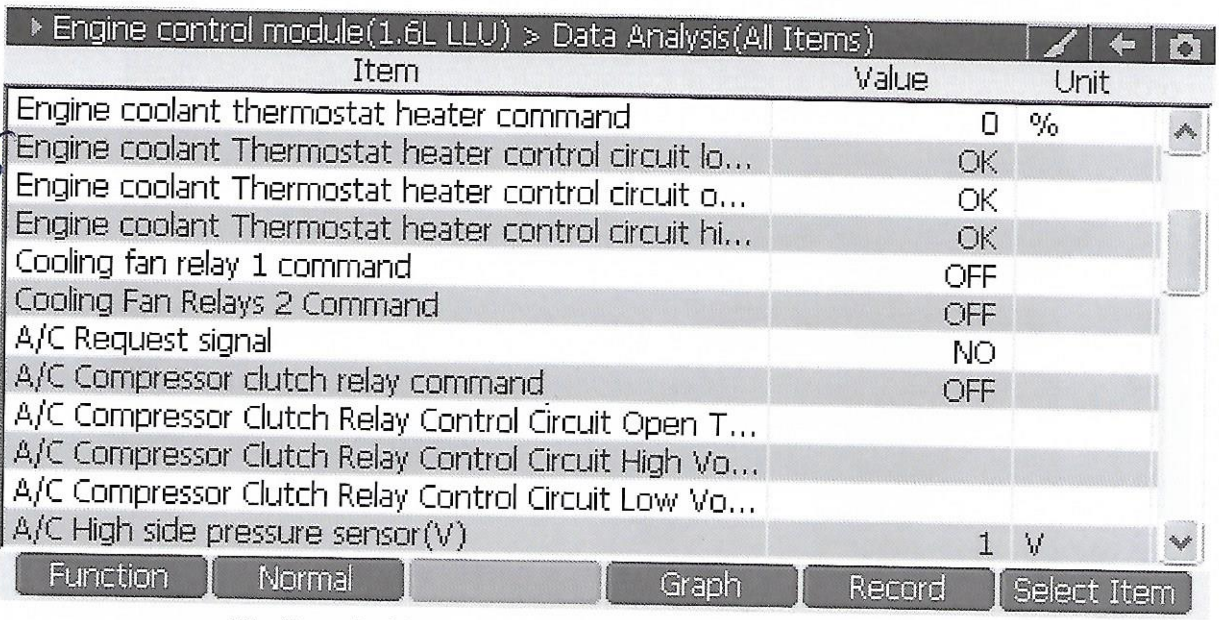
note - Computor monitored circuits are monitored via voltage.

* crucial that inputs are good for Disired & Acutal.

ie MAF, Crank, TPS, Acc Pedal - inputing correctly

THERMAL MANAGEMENT SYSTEMS continued...

Holden Cruze (all petrol engines)
All petrol Cruze models utilise an electronically controlled thermostat. Holden do not state the exact condition in which the engine is allowed to operate at elevated temperatures, but they can be monitored on a compatible Scan Tool.

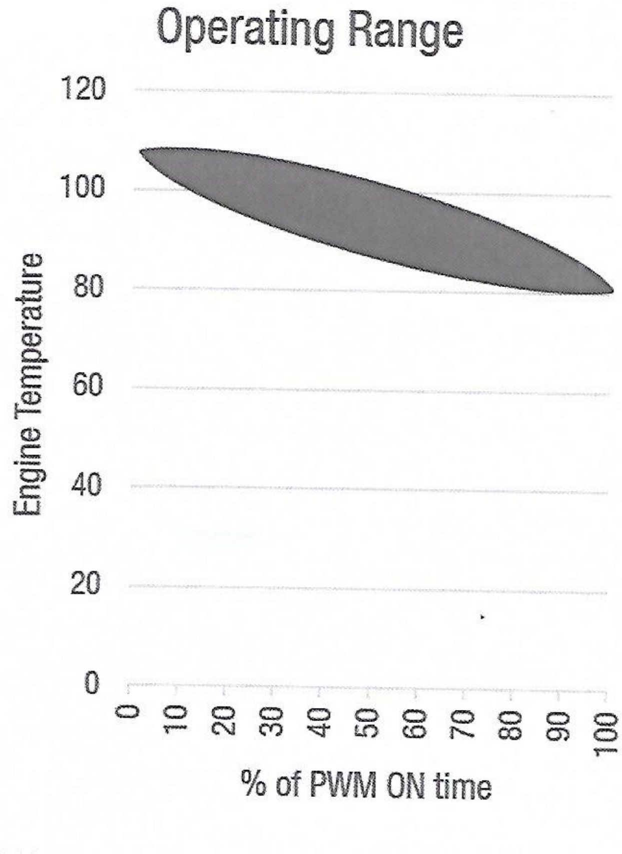


▸ Engine control module(1.6L LLU) > Data Analysis(All Items)

Item	Value	Unit
Engine coolant thermostat heater command	0	%
Engine coolant Thermostat heater control circuit lo...	OK	
Engine coolant Thermostat heater control circuit o...	OK	
Engine coolant Thermostat heater control circuit hi...	OK	
Cooling fan relay 1 command	OFF	
Cooling Fan Relays 2 Command	OFF	
A/C Request signal	NO	
A/C Compressor clutch relay command	OFF	
A/C Compressor Clutch Relay Control Circuit Open T...		
A/C Compressor Clutch Relay Control Circuit High Vo...		
A/C Compressor Clutch Relay Control Circuit Low Vo...		
A/C High side pressure sensor(V)	1	V

Fault codes

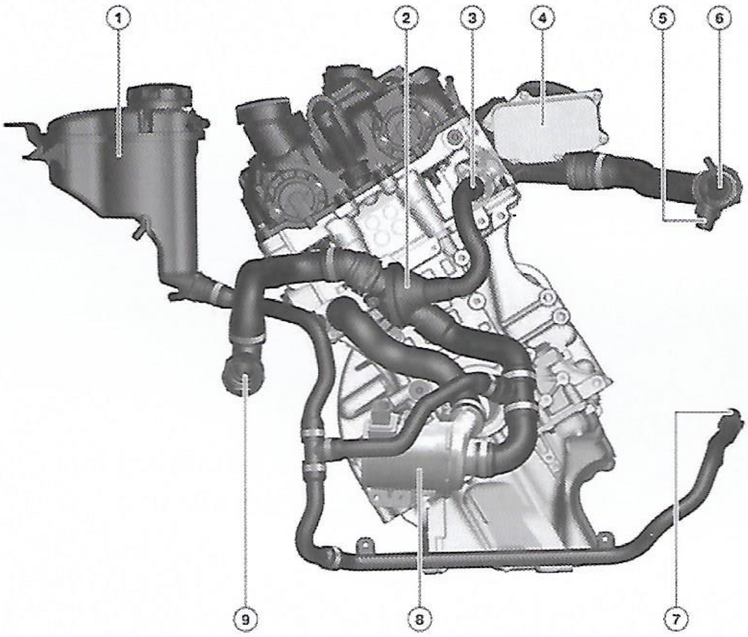
The Scan Tool Data for the Cruze showing the command at 0%

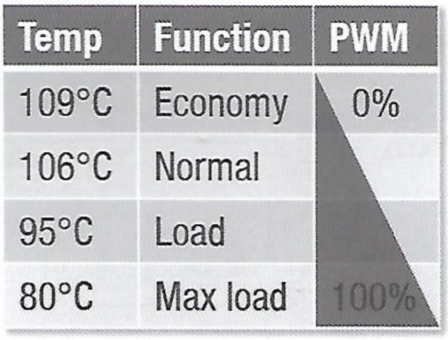


Thermostats for Holden Cruze, 1.8L DT158Q [upper] 1.6L DT159Q [centre] 1.4L OEM only [lower]
Table showing temperature operating vs ECM control

THERMAL MANAGEMENT SYSTEMS continued...

BMW N20 Petrol Engine
BMW started using electronic thermostats in the E39 (mid 1990's) and progressively introduced them across the entire range until all petrol engines were using them by the mid 2000's. BMW are a little more forthcoming with operational specifications as shown in the table below:





Temp	Function	PWM
109°C	Economy	0%
106°C	Normal	
95°C	Load	
80°C	Max load	100%

Key:
1. Expansion Tank
2. MAP Thermostat
3. Engine return, bypass circuit
4. Engine oil to coolant heat exchanger
5. Feed, heater core
6. Feed, radiator
7. Return, heater core
8. Electric coolant pump
9. Return, radiator

*EGR Coolers crack due to excessive thermal shock.

Must put the right coolant in the right eng for Australia - important the PH is not acidic in cooling system (7.5 - 8 APPROX) Turns cooling system into a Battery.

THERMAL MANAGEMENT SYSTEMS continued...

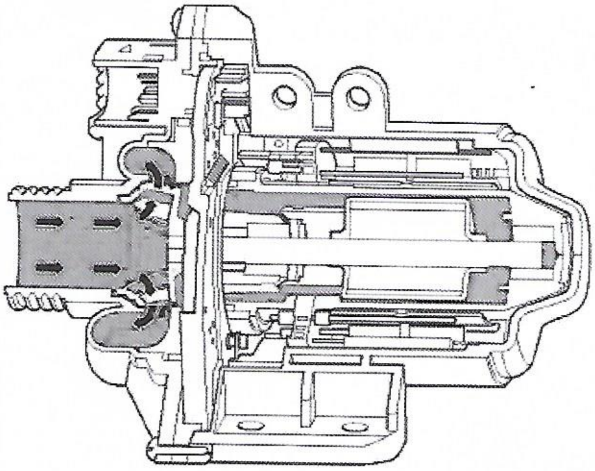
Electronic Water Pumps

There are two ways in which electronic water pumps are used in production cars. They can either replace the existing belt driven pump (Full System Electric Coolant Pump) or they can be additional to the existing belt driven pump (Sub-System Electric Coolant Pump).

Full System Electric Coolant Pumps

The major benefit of the Full System Electric Coolant Pump is the reduction in parasitic load but also extends to the ability to continue flowing after engine shutdown to allow the engine temperature to stabilise.

Caution:



The bearings in the coolant pump are cooled and lubricated by the coolant (shown in grey).

Ensure that coolant is up to scratch!

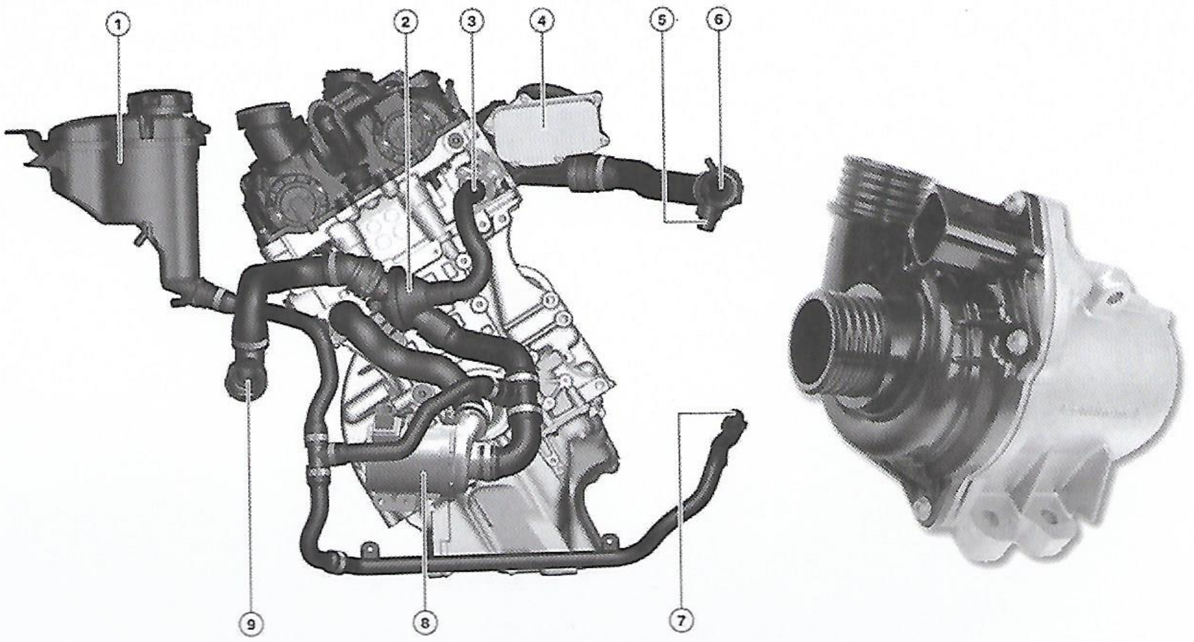
Store used pump FULL of coolant to prevent the bearings from sticking!

THERMAL MANAGEMENT SYSTEMS continued...

BMW N20 Petrol Engine

Integration of electric water pumps on petrol BMW's began with the V8's in early 2000's. This led to full integration, firstly in the 6 cylinder N52 engines (from mid 2000's) and then the N20 4 cylinder turbo engines.

There is about a 5 year delay on most of the BMW engines from EU release to when they arrived in Australia, it is very hard to investigate exact dates as there may have been some low volume M sport variations that used the technology earlier.



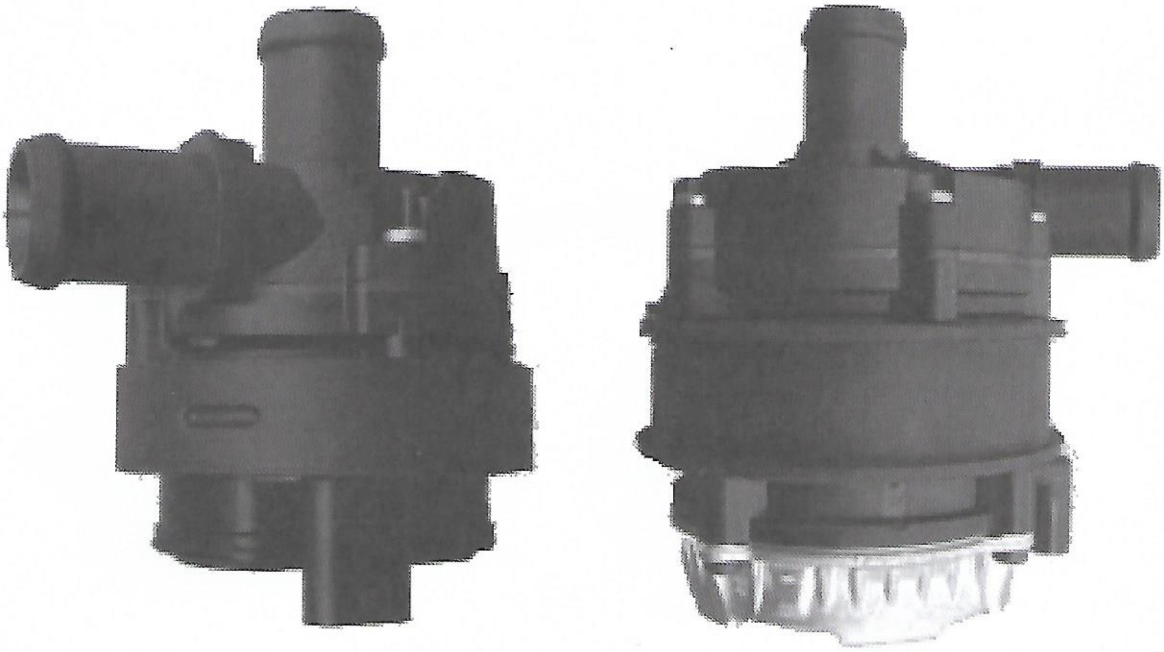
Key:

1. Expansion Tank
2. MAP Thermostat
3. Engine return, bypass circuit
4. Engine oil to coolant heat exchanger
5. Feed, heater core
6. Feed, radiator
7. Return, heater core
8. Electric coolant pump
9. Return, radiator

THERMAL MANAGEMENT SYSTEMS continued...

Sub-System Electric Coolant Pumps
Sub-System Electric Coolant Pumps are used to control the cooling ancillary devices in the engine bay, these include:

- Turbochargers
- Hybrid Electric Motors
- EGR Coolers



Bosch Auxiliary Coolant Pumps

EGR coolers benefit from running at temperatures below the regulated engine temperature. Complex cooling systems have radiators that cool the coolant well below the desired temperature and then bleed hot coolant into the thermostat to achieve the desired temperature. Vehicles with EGR Electric Coolant Pumps draw the coolest coolant from the system and send it directly to the EGR Heat Exchanger.

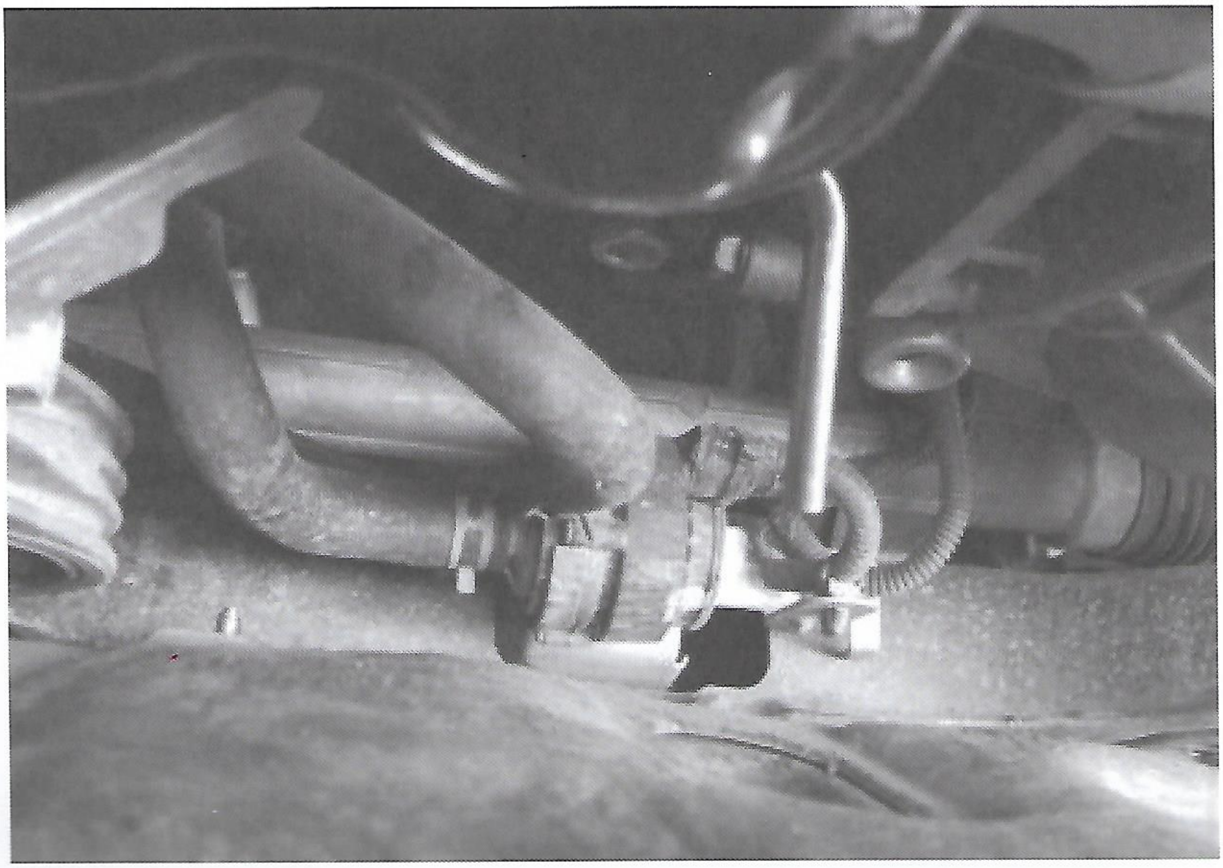
Turbochargers and Hybrid Electric Motors need cooling when the Internal Combustion Engine (ICE) has shut down. Sub-System Electric Coolant Pumps provide coolant flow during normal operation as well as when the ICE is disabled.

THERMAL MANAGEMENT SYSTEMS continued...

Nissan T31 X-Trail
The T31 X-Trail was available with a Renault derived M9R 4 Cylinder Turbo Diesel Engine. The cooling system includes a Turbocharger Coolant Pump located on the cross-member / sub-frame below the engine.

Continues coolant flow around Turbocharger after engine is shut down, under following conditions:

- Coolant temperature >80°C
- Engine OFF
- Maximum of 5 minutes



Note: *The Turbocharger Coolant Pump is NOT used when the engine is running!*

COOLANT

Coolant Types

There are two types of coolant:

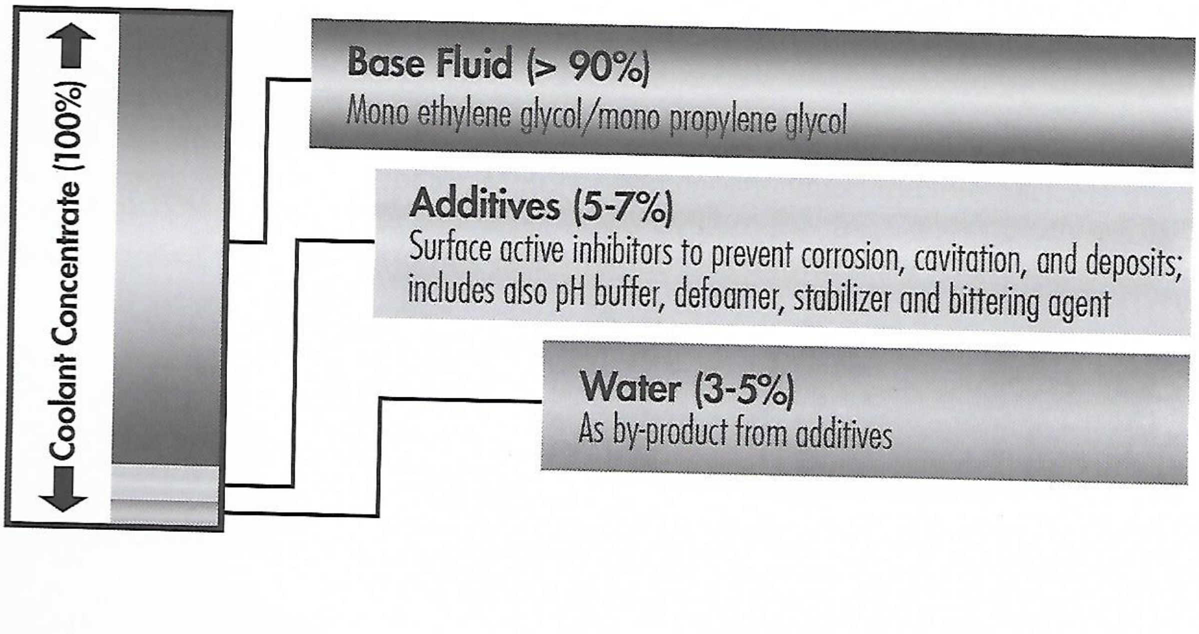
Type 'A' - Containing Glycol, Inhibitors and Water
Type 'A' coolants are know as Anti-Freeze / Anti-Boil
These are available in a concentrate that is used at between 30/70 to 50/50 (preferred) coolant to water ratio and as a premix with demineralised water.

Type 'B' - Contain only Inhibitors and Water (NO Glycol)
Type 'B' coolants have no affect on the boiling or freezing temperatures, only providing the corrosion and scale inhibitors, pH buffers, defoamers and anti-cavitation properties. These are generally available only as a concentrate and are are used between 1/10 to 1/20 coolant to water ratio. These are not usually sold as a premix and because of their mix ratio are normally sold in 500mL-2.5L botlles.

Coolant Chemistry

$H^{2}0$ – Water
IAT – Inorganic Acid Technology
OAT – Organic Acid Technology
HOAT – Hybrid Organic Acid Technology

Why did we list water in the list of coolant technologies, simply because it makes up the highest percentage of the liquid with the Cooling System. Most automotive Type 'A' coolants are Ethylene-Glycol (EG) but a less toxic, more environmentally friendly version exists called Propylene-Glycol (PG). However, it is used mainly in food production equipment.

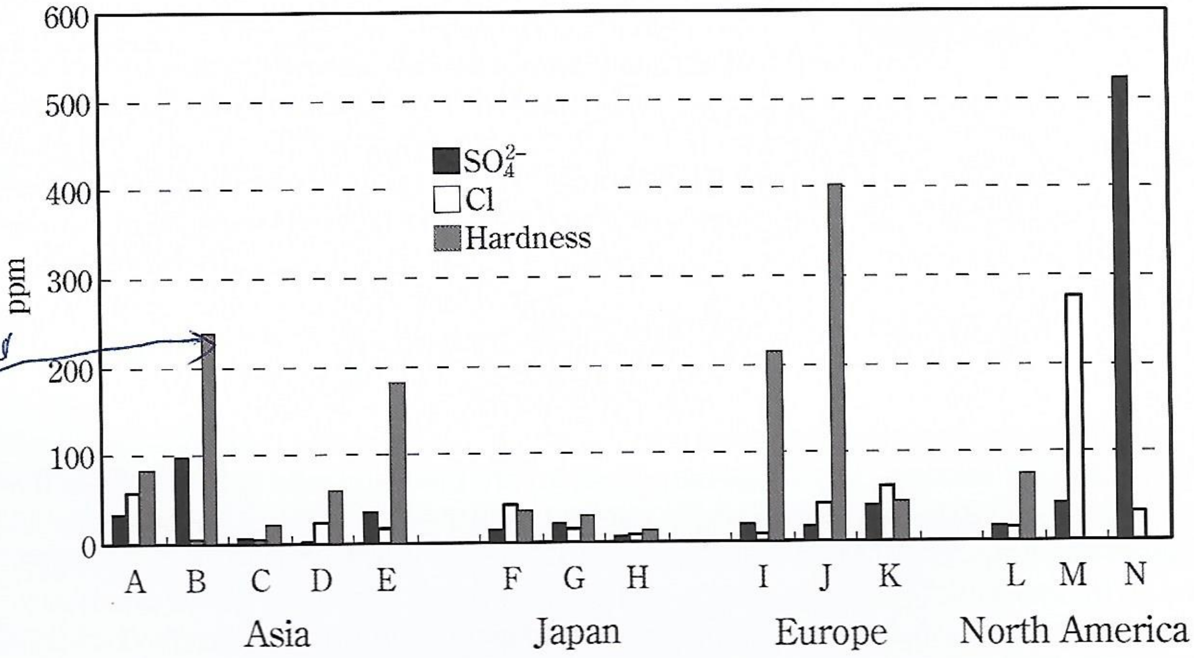

Coolant Concentrate (100%)
Base Fluid (> 90%)
Mono ethylene glycol/mono propylene glycol
Additives (5-7%)
Surface active inhibitors to prevent corrosion, cavitation, and deposits; includes also pH buffer, defoamer, stabilizer and bittering agent
Water (3-5%)
As by-product from additives

COOLANT continued...

The Glycol generally does not degrade, it is the additives that are depleted. Both OAT and HOAT coolants are considered long life coolants (LLC) or extended life coolants (ELC). IAT's are standard coolants and usually have a replacement interval of 2-3years.

The types of additives have stemmed from two key driving forces:

1. The chemical make-up of localised water
2. The materials used in construction of the engine and its cooling system



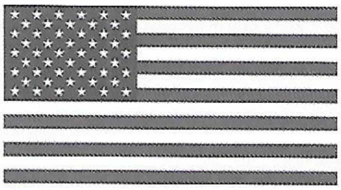
Most water around here.

The mineral make-up of local water can be easily seen in this graph, it shows varying levels of sulphates (SO) and naturally occurring chlorine (CL) as well as the waters hardness. Hard water contains higher quantities of calcium and magnesium. Australia is roughly at both A and B.

- Phosphates react with hard water.
- Must use Deminalised water in cooling systems
-

COOLANT continued...

Traditionally, coolants deriving from Europe were free of Phosphates and were low in silicates while coolants from Japan were free of Silicates but high in Phosphates. Coolants produced in the USA were typically high in both Phosphates and Silicates as well as Borate and Nitrite.



Europe	**Japan**	**America**
Ethylene-Glycol	**Ethylene-Glycol**	**Ethylene-Glycol**
Benzoate	**Phosphates**	**Borate**
Low Silicate	**Amine**	**Nitrite**
~~**No Phosphates**~~	~~**No Silicates**~~	**Phosphates**
		Silicates

Today these coolants have evolved into the three coolant types that are found on the shelves of retailers. The American coolants are the traditional (by Australian standards) coolants that were used in cars up until the mid 1990's. These are known as Inorganic Additive Technology or IAT. It is important to understand that the term 'Inorganic' does not refer to the product being synthetic, but in chemistry 'Inorganic' means that the chemical compound lacks Carbon to Hydrogen bonds (C-H bond). The European coolants evolved into what is known today as Organic Additive Technology or OAT coolants and the Japanese coolants have evolved into Hybrid Organic Additive Technology or HOAT (sometimes just HAT).

Additives
There are many different additives used in blending coolants, we'll focus on the key ones:

Silicates
Silicates are derived from sand, they are an IAT. They are very effective at creating a quick and strong bond between the water and aluminium. There is some suggestions that the nature of the silicates (crystals) are abrasive particularly to moving parts such as the water pump.

COOLANT continued...

Phosphates

Phosphates are derived from minerals that are rich in phosphorus and are an IAT. They are very effective at creating a quick and strong bond between the water and all metals found in automotive cooling systems. The downside of phosphates is that they produce scale which over time will create a shield between the metal components and the water reducing the efficiency of the cooling system.

2-ethylhexanoic acid (2-EHA)

2-EHA was used primarily by General Motors (and GM Holden) in the early 1990's in the company's transition from IAT to OAT coolants. It provides a good bond between cast iron and water and it was the "special ingredient" that was used in AC Delco coolant for the GM HFV6 engines. It has one very serious con and that is it is a plasticiser and will soften (destroy) plastic components within the cooling system. 2-EHA has now been replaced with Benzonate.

Benzonate

Benzonate is an OAT and is the most commonly found additive in modern OAT Coolants, It provides a good bond between cast iron and water as well as performing reasonably for aluminium.

Sebacate

Sebacate is an OAT additive that provides an excellent bond between the water and aluminium, but it is slow bonding. It has a very serious con if used in the incorrect applications as it attacks both copper and solder. Sebacate is found in some OE coolants including VW, Toyota Pink (not red), Honda and GM.

Amine

Amine was used as a PH Buffer, it is carcinogenic and was banned in Scandinavia in 1987. It is not a commonly used additive today.

Borate

Borate is an IAT and is used predominantly as a scale inhibitor, it is environmentally toxic and it use today is limited.

Triazoles

Triazoles are an IAT and are a particularly good corrosion inhibitor for copper.

Nitrites

Nitrites are an IAT where they are used as a defoamer, but are also used in HOAT coolants as an agent that allows the IAT components to blend with the OAT components without negative effects.

NAPS-free

This term is starting to gain momentum in the Automotive Industry and it refers to OAT's and means that they contain no Nitrites, Amines, Phosphates or Silicates.

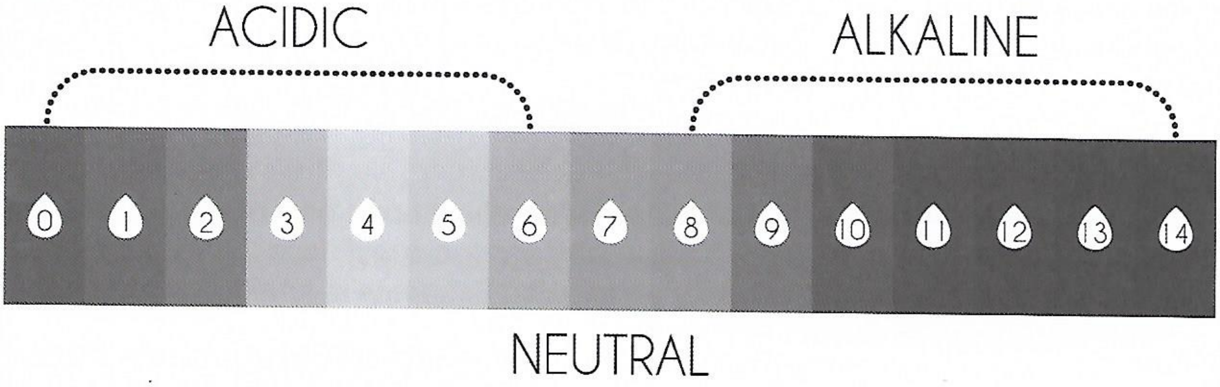
COOLANT continued...

Testing Coolants

There are two things that we need to verify with the coolant. Firstly, the concentration of the ethylene glycol content. This is the coolants anti-freeze and more importantly for most Australians anti-boil. At the preferred 50/50 mixture the boiling point is increased from 100°C to 106°C. The ethylene glycol concentration can be measured in a variety of ways:

- Hydrometer
- Refractometer
- Test Strip

The second component of coolant that needs to be analysed is the pH level. Most coolants are manufactured with a pH level of between 7.5 and 8.5, making them Neutral to slightly Alkaline. Over time the coolant will become acidic and this will be detrimental to the components that make up the cooling system. The easiest way of checking the coolants acidity is with Coolant Test Strips.

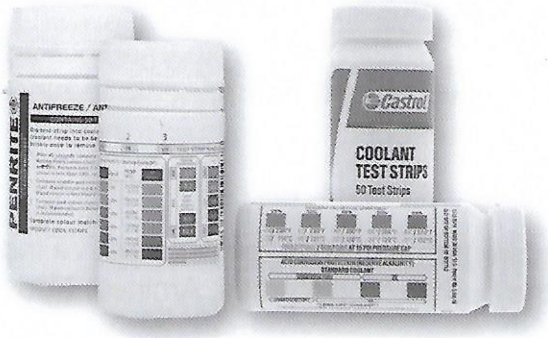


Caution:

Cross contamination of coolants due to not flushing or topping up with a different coolant will reduce the Reserve Alkalinity (RA) and cause the coolant to turn acidic rapidly!

Coolant Test Strips

The advantage in test strips is that they test the acidity and the ethylene glycol concentration in a single test.



COOLANT continued...

Flushing
Many technicians believe that flushing a cooling system is only required when there coolant is dirty or if there are suspected blockages. This is not the case. The residual coolant that is left in the system may be acidic and will have a reduced Reserve Alkalinity (RA) which is the coolants ability to remain in the Neutral to Slightly Alkaline range. The RA of new coolant is designed to last the service life of the product, if 30% of the old coolant is left in the cooling system the serviceable life of the new coolant will be reduced from say for example 5 years to 3.5 years. This would allow for up to 1.5 years of acidic coolant eating away at the vehicles components.

For vehicles with extremely complex cooling systems, traditional flushing may not be a viable option. Some manufacturers require a triple change procedure:

1. Original coolant is drained
2. The system filled with water only
3. Engine run to operating temperature
4. The system is drained again
5. Then filled again with water only
6. Engine run to operating temperature
7. The system is drained again
8. The system is filled with coolant as per manufactures specifications

Another option is to use an automated coolant exchanging machine which evacuate, flush and fill the vehicles cooling system automatically.

*Coolants must not be mixed period its the additives that react in coolants

* Bi-Directionally open thermal management systems with scan tools then flush.

MOTORVAC
MOTORVAC

*Alkaline Salts is Great for neutralizing Acids
this is in Coolant flush fluids

DIAGNOSING ENGINE TEMPERATURE ISSUES

Discuss the fault with the vehicles driver

- What temperature is the gauge showing?
- When does the fault occur (towing / up-hills / cold morning / hot day)?
- Has anyone looked into this fault previously?

Check the Basics

Coolant Level and leaks

If low, pressure test for leaks and carry out a full visual inspection. If no leaks are found check for traces of CO2 in the cooling system using a Combustion Leakage Tester. If the vehicle is fitted with heat exchangers (EGR Cooler, Oil Cooler, Fuel Cooler, Transmission Cooler) check for coolant escaping into those systems.

Note: *Many CRD engines have issues with failing EGR Coolers, it usually starts as a slow drop in coolant level with no evidence due to the coolant vaporising inside the exhaust. This eventually leads to a larger leak with visible white pungent steam from the exhaust! Failure to top up the coolant level leads to engine failure.*

Vehicles with known issue:

- *Holden Rodeo & Colorado 4JJ1 engine*
- *BMW's with N47 CRD engines*
- *Land Rover, Ford and others with TDV6 eng.*
- *VW 1.6 and 2.0L CRD engines*
- *Ford Ranger and Mazda BT-50*
- *Nissan Navara & Pathfinder with YD25 eng.*
- *Mitsubishi Pajero & Triton with 4M41 eng.*

DTC's

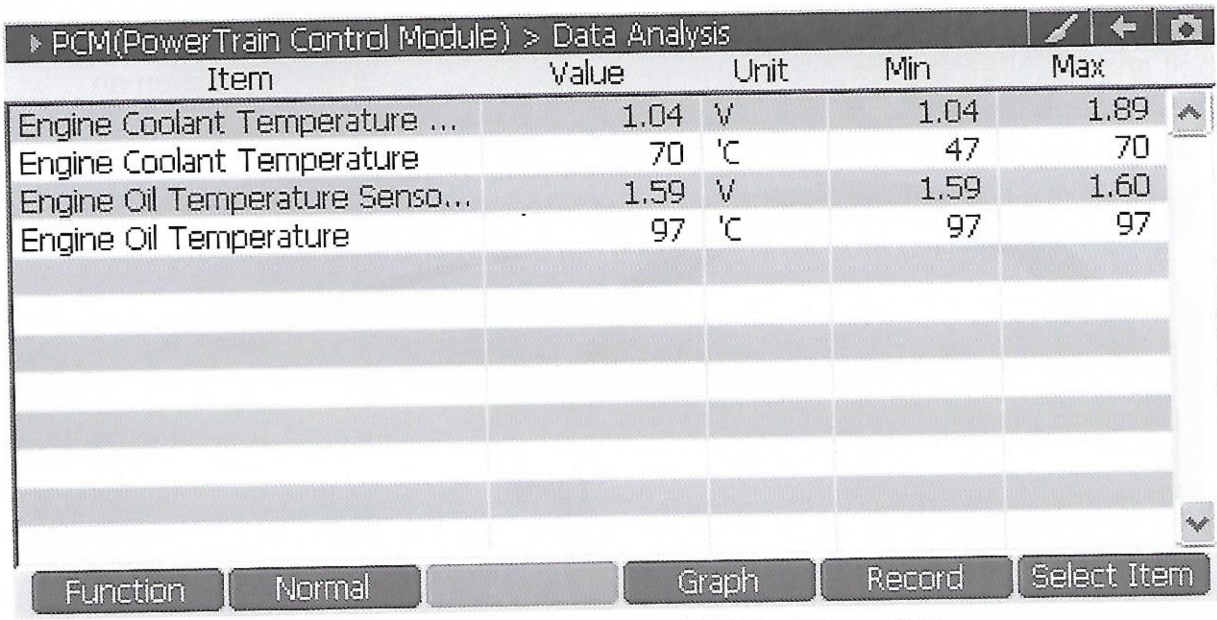
If any DTC's are logged they should be addressed before investigating the overheating concern.

DIAGNOSING ENGINE TEMPERATURE ISSUES continued...

Check Live Data

The vast majority of vehicles today have the Temperature Gauge relaying the Coolant Temp value from the Engine ECU. Modern vehicles don't often have calibration issues with the temperature gauge but it is a quick and easy test.

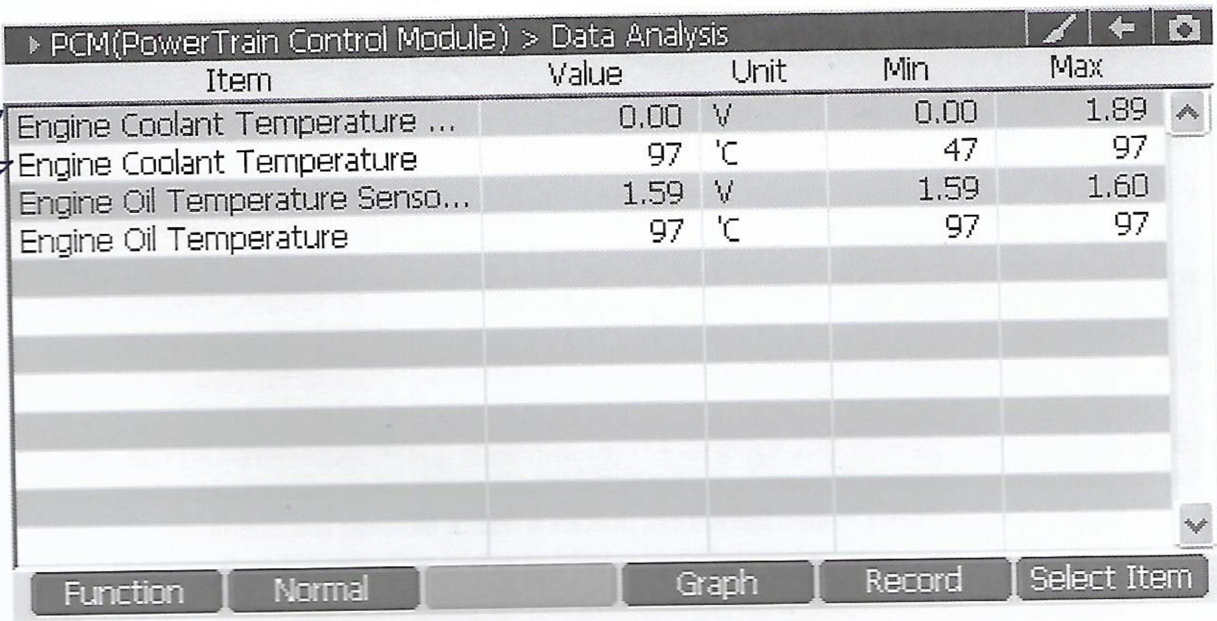
Compare the temperature values that are available, many European vehicles will also have an Oil Temp Value. The oil temperature will fluctuate much slower than coolant temp but after a steady test drive the two values should be within 10% of each other.



PCM(PowerTrain Control Module) > Data Analysis

Item	Value	Unit	Min	Max
Engine Coolant Temperature ...	1.04	V	1.04	1.89
Engine Coolant Temperature	70	'C	47	70
Engine Oil Temperature Senso...	1.59	V	1.59	1.60
Engine Oil Temperature	97	'C	97	97

This data was captured from a 2011 Ford Ranger 3.2L



open circuit

Sbstituted

always check volts

PCM(PowerTrain Control Module) > Data Analysis

Item	Value	Unit	Min	Max
Engine Coolant Temperature ...	0.00	V	0.00	1.89
Engine Coolant Temperature	97	'C	47	97
Engine Oil Temperature Senso...	1.59	V	1.59	1.60
Engine Oil Temperature	97	'C	97	97

To highlight a possible cause for misdiagnosis the Engine Coolant Temperature Sensor was disconnected. Notice how the ECU has inferred the temperature value from the oil sensor. The tell tale is that the voltage value has dropped to 0 Volts (it also logged a P2184 DTC).

DIAGNOSING ENGINE TEMPERATURE ISSUES continued...

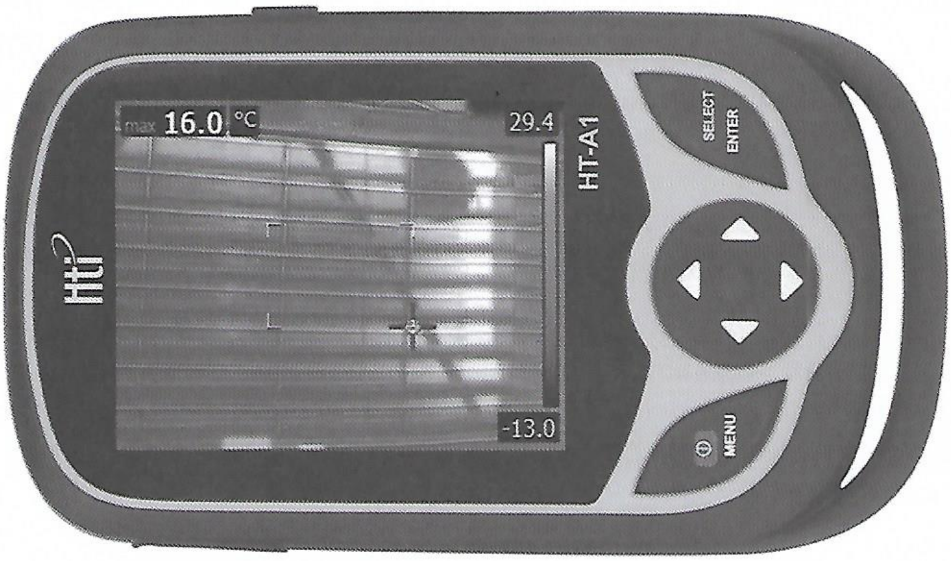
Verify the Coolant Temp Sensor Values
If there is a suspicion that the Coolant Temp Sensor may be outputting an inaccurate value there are a few ways that its accuracy can be clarified. The oldest and simplest way was to compare the sensors resistance value against its temperature, unfortunately less and less manufacturers are providing this data. Another option can be comparing the Scan Tool Data value against a thermometer. An infrared thermometer can be used to measure the temperature directly adjacent to the sensor. Do this at various temperatures to get an accurate cross-reference.

If temperature readings are required while the vehicle is on a road test then a Type-K Thermocouple with an eye-ring can be placed under the head of any bolt and will allow the temperature to be displayed on a multimeter or even an oscilloscope while driving.

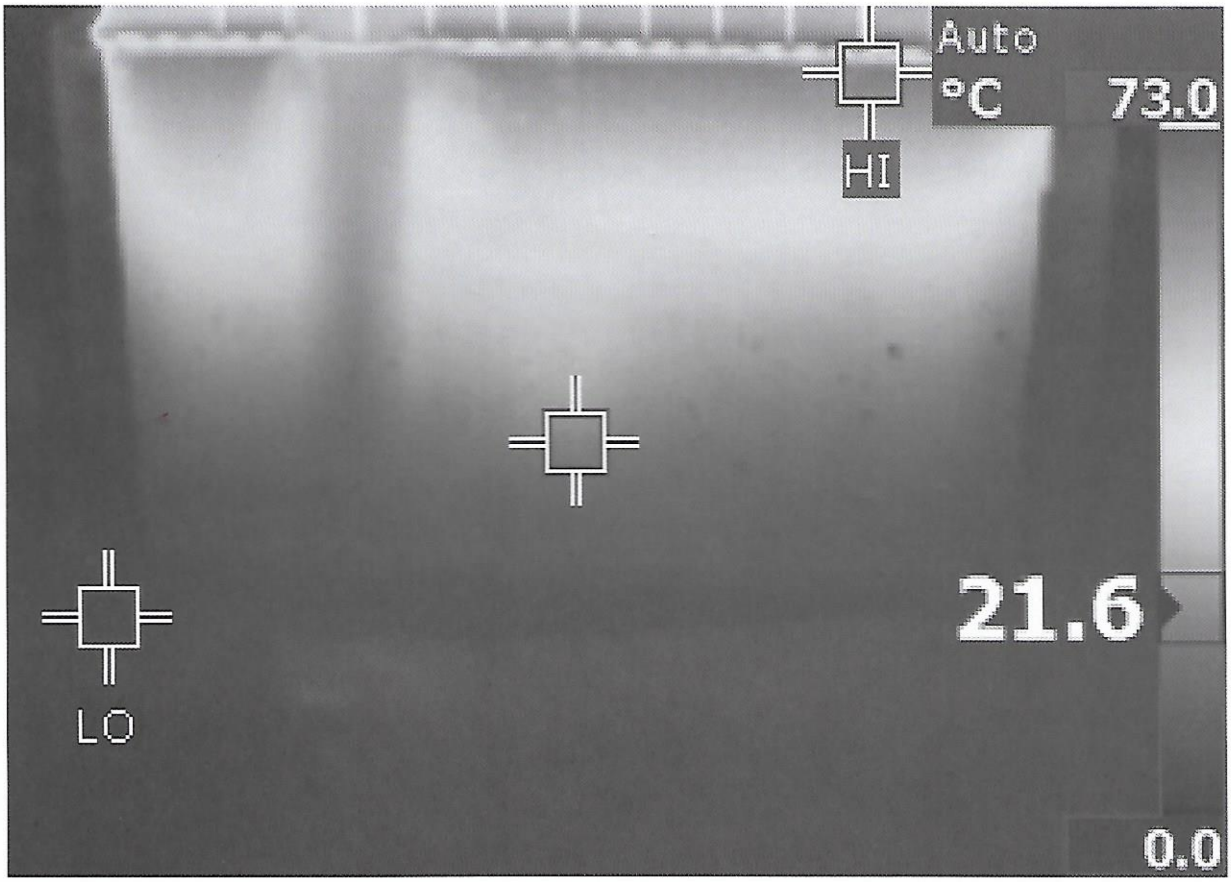
Type-K Thermocouples are compatible with most Multimeter's and Oscilloscopes

Check temperature distribution around the cooling system
Thermal imaging cameras are becoming more affordable and can be a handy diagnostic tool for many vehicle systems. They take cooling system diagnostics into an entirely new dimension. Giving the ability to visually see in real-time not only the changing temperature of components but also the accurate temperature readings.

DIAGNOSING ENGINE TEMPERATURE ISSUES continued...


max 16.0 °C
29.4
-13.0
HT-A1
SELECT
ENTER
MENU
Hti

Crossflow radiator in a Land Rover Defender, warm coolant enters on the right side of the image (round circle is the horn which is located in front of the radiator).


Auto
°C
73.0
HI
21.6
LO
0.0

In this image it is possible to see a section (on the left side of centre) of the radiator is cooler than the rest. This is due to blocked tubes reducing coolant flow and allowing the ambient air to cool that section with greater effect.

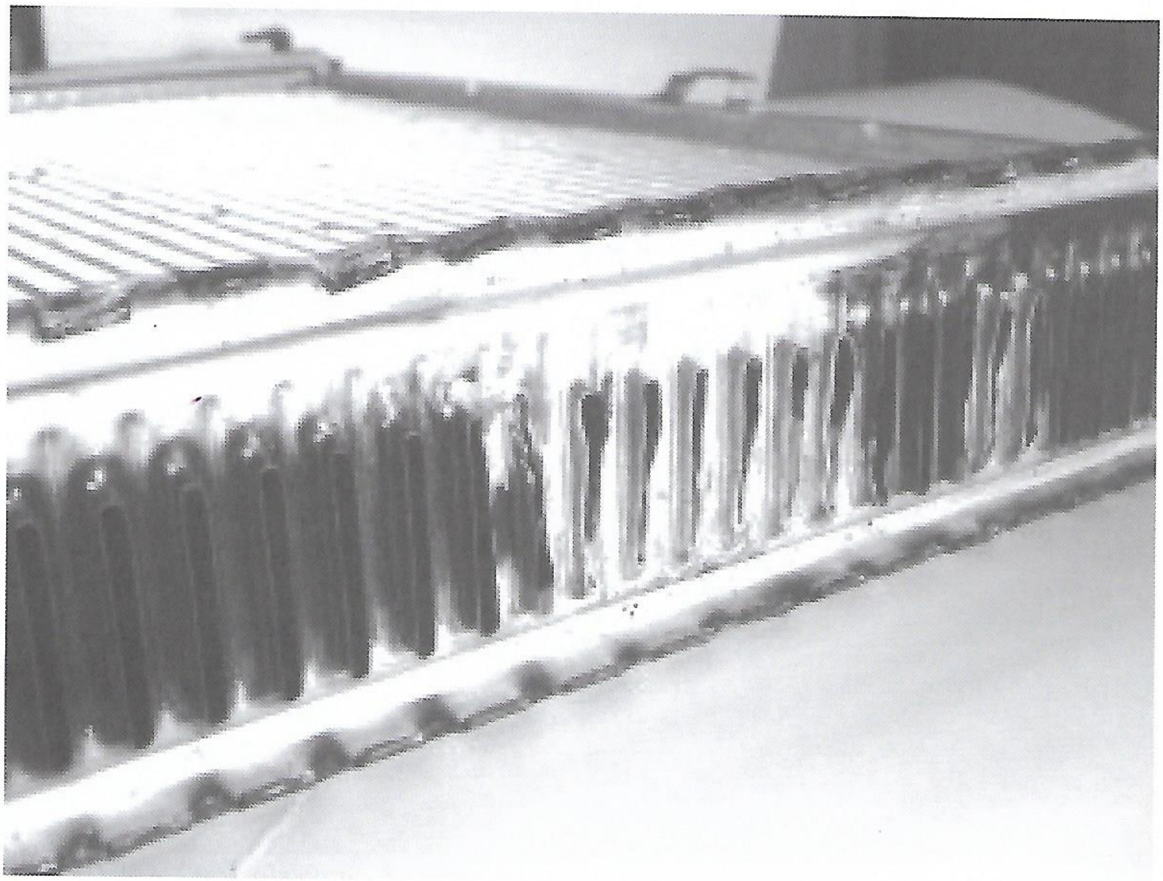
max 100 milli volts or corrosion will occur.

DIAGNOSING ENGINE TEMPERATURE ISSUES continued...

Stray Current (Electrolysis)
If a vehicle presents with a radiator core failure it will be imperative to carry out a stray current test. Stray current comes from electrical components on the engine that normally receive their grounding at the chassis via the engine block. If the ground wire/s from the engine to the chassis are damaged the current will always search for its easiest path to ground. If that path is via the radiator the current will quickly erode the radiator core usually resulting in one or multiple pinhole sized leaks.

Vehicles that have not had stray current detected have been known to destroy a new radiator in as little as 6 weeks. Radiator manufactures know exactly how to identify the cause and will not provide a parts warranty where stray current was the cause of failure.

Electrolysis will turn the bright aluminium on the inside of the radiator to a dark grey, when left to dry the internal surfaces will become powdery, this is the corrosion that is a direct result of stray current.

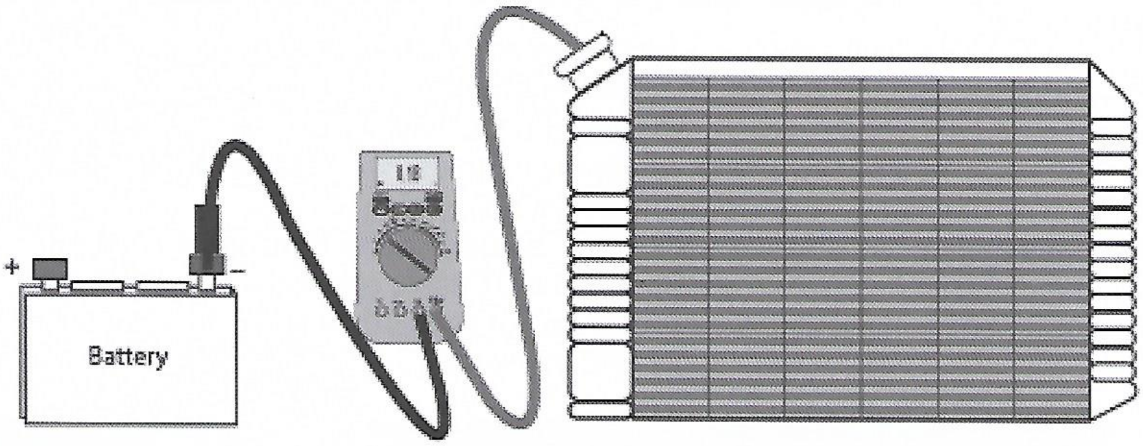


White powdery residue and tube damage are the result of stray current

The correct coolant concentration can reduce electrolysis so always check that the coolant is up to scratch. In fact if the coolant becomes acidic it can turn the cooling system into a battery, this is a result of a chemical reaction between the acid and the different metals used throughout the system.

DIAGNOSING ENGINE TEMPERATURE ISSUES continued...

To test for Stray Current

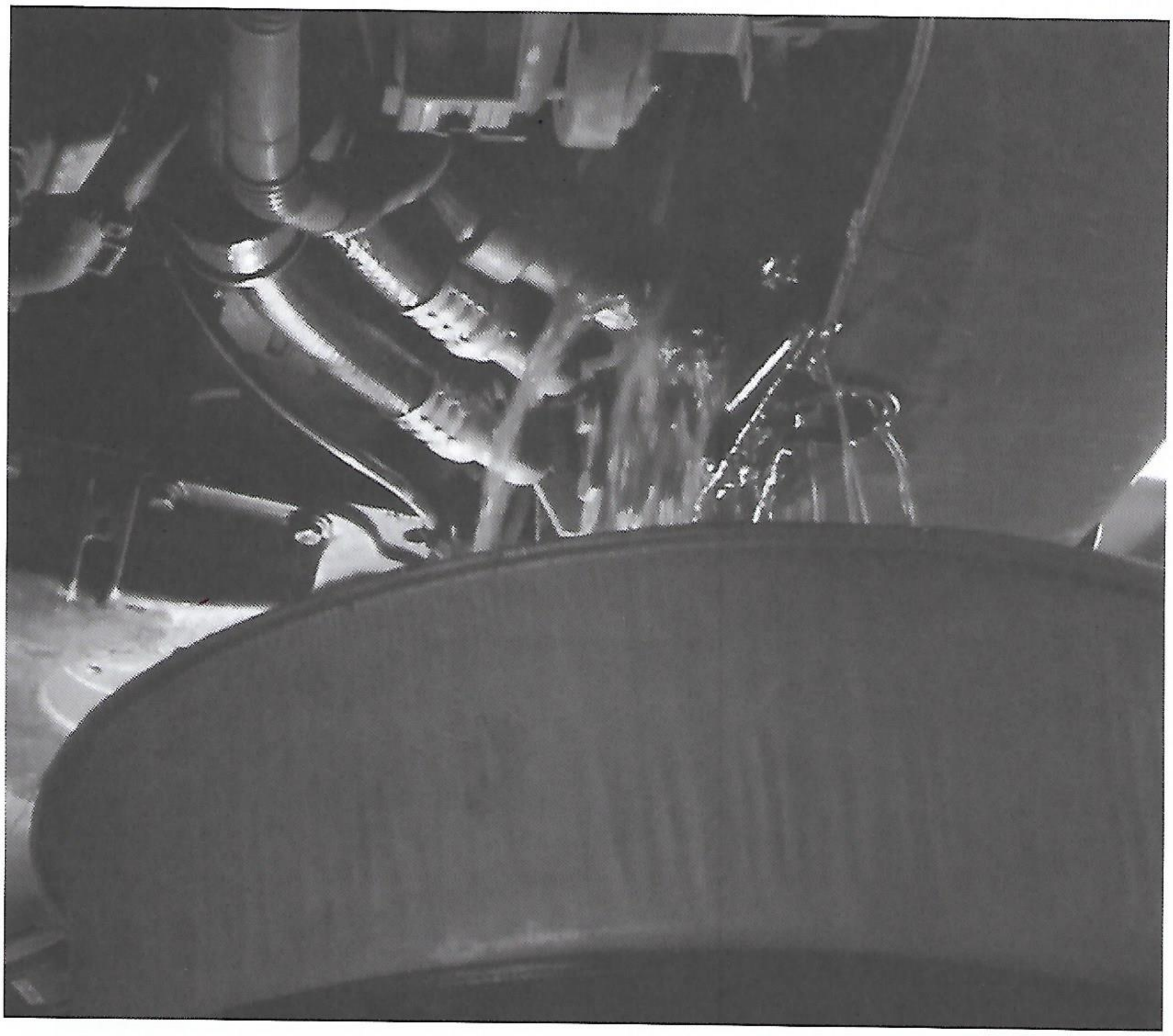


1. Attach the negative lead of a multimeter to the negative battery terminal
2. Attach a small piece of copper to the end of the positive lead and hand it in the coolant at the location of the pressure cap
3. With the Ignition OFF measure the voltage, if higher than 0.25 Volts the coolant is acidic and must be replaced
4. Start the engine and check the voltage at idle
5. Increase engine speed to 2000 RPM and check the voltage again
6. Turn on all of the electrical loads and check the voltage yet again
7. If any of the above tests cause the voltage to exceed 0.25 Volts the cause of the stray current must be identified and rectified.
8. Before putting away the multimeter, check the output voltage of the alternator and ensure that the system isn't overcharging.

* must use an analoge multimeter as Digital meter Puts out some current to measure volts, usally 250 millivolts.

SIMPLE RULES FOR CHANGING A COOLANT

1. No two coolants are truly compatible (the additives can counteract each other)
2. Always fully flush out old coolant – can add Alkaline flush additive(old coolant turns acidic, it will deplete the new pH balancers)
3. In a perfect world we'd always refill with OE
4. We're not in a perfect world so always try to use the listed alternative
5. If no listing is available use a hybrid (HOAT) coolant
6. If the engine has a lot of cast iron use a coolant with Benzonate
7. If the engine has plastic housings DO NOT use a coolant with 2-EHA
8. If the vehicle has a copper radiator do not use OAT or HOAT that contains Sebacate (it will eat the copper and the solder)



SPECIAL SERVICE TOOLS

Name	Part Number
Cooling System Evacuation Kit	SCMT70880
Automatic Coolant Flush & Exchange Machine	500-5100P
Infrared thermometer	RST195
Thermal imaging camera	ET2027
Thermocouple w/ eye-ring (Type-K)	

Section ii

Climate Control Systems

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Section ii

Climate Control Systems

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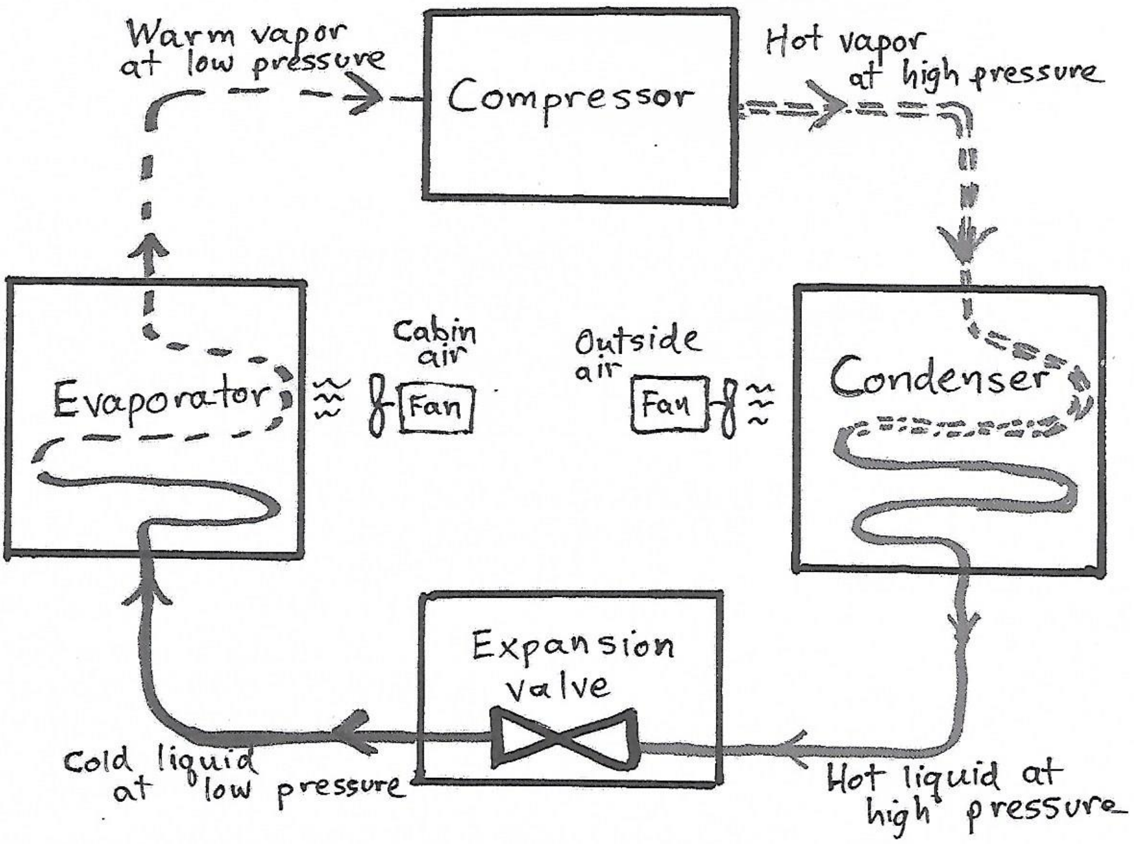
INTRODUCTION

What does A/C do?
It shifts heat from inside the car to the outside of the car.


Warm vapor at low pressure
Compressor
Hot vapor at high pressure
Cabin air
Fan
Outside air
Fan
Evaporator
Condenser
Expansion valve
Cold liquid at low pressure
Hot liquid at high pressure

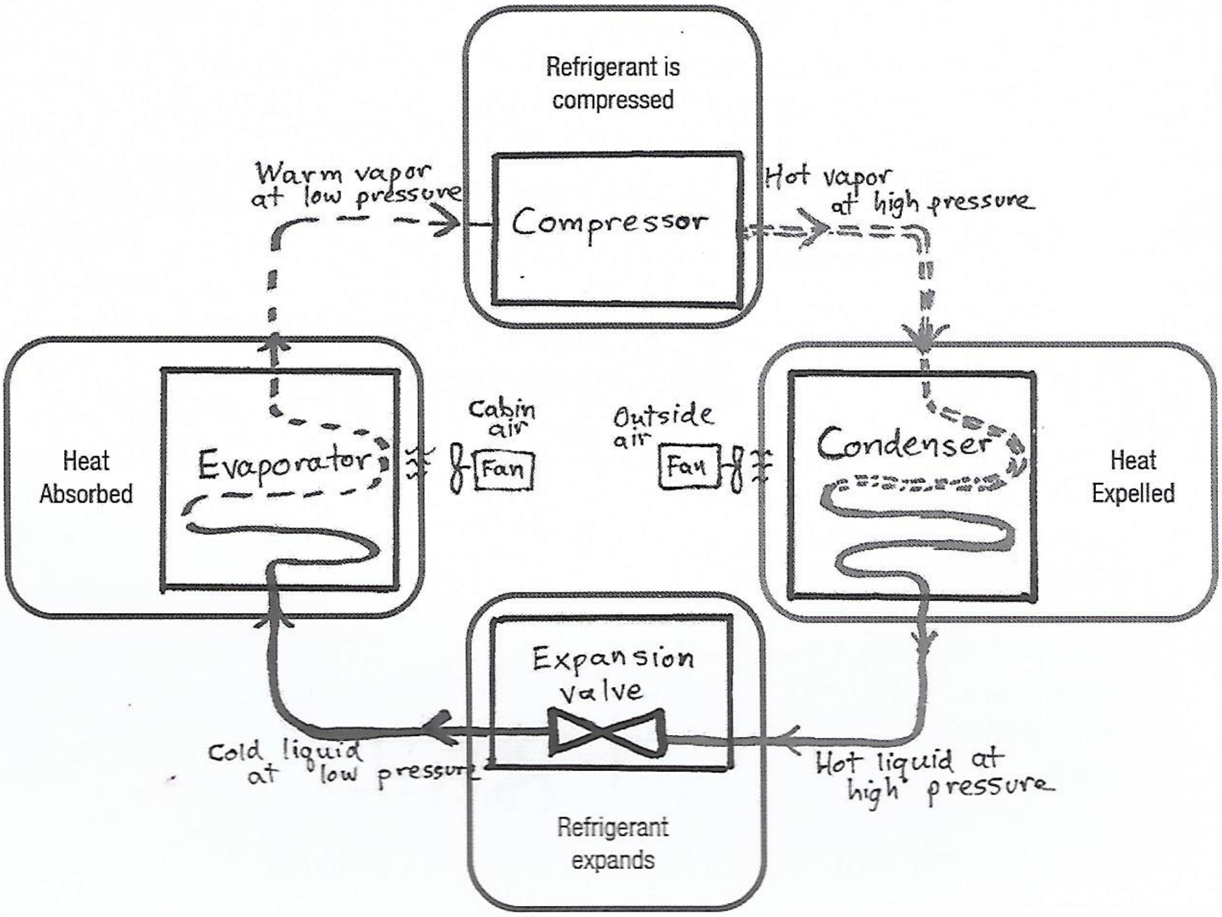
When you put your hand in front of an A/C vent, it may seem that an air conditioner creates cold air. But in reality, it has only moved the thermal energy from inside your car to the outside atmosphere.

*Thermal energy ALWAYS flows from warmer to cooler,
this means that the Compressor and the Expansion Valve control the system.*

INTRODUCTION continued...

Expansion Valve function

The expansion valve removes pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapour in the evaporator. As the pressure drops the thermal energy expands into a much greater area causing the temperature of the refrigerant to drop substantially. This makes the evaporator much cooler than the cabin air that passes over it, the thermal energy in the cabin air is transferred to the refrigerant and the air coming out of the vents is cooler.


Refrigerant is compressed
Compressor
Warm vapor at low pressure
Hot vapor at high pressure
Heat Absorbed
Evaporator
Cabin air
Fan
Outside air
Fan
Condenser
Heat Expelled
Expansion valve
Cold liquid at low pressure
Hot liquid at high pressure
Refrigerant expands

Compressor function

Keeping in mind that thermal energy ALWAYS flows from warmer to cooler, refrigerant exiting the evaporator (and the cabin) is still cooler than the ambient air in the atmosphere (and the engine bay) which means that without assistance the refrigerant would absorb more heat rather than expelling it into the atmosphere. This is where the compressor comes in, using mechanical energy (or electrical energy in Hybrid/Electric vehicles) the compressor increases the refrigerant pressure. This crams all of the thermal energy held in the now vaporous refrigerant to be compressed into a very small space causing the refrigerant to be superheated. Now the refrigerant entering the condenser is much warmer than the atmospheric air passing over it, the thermal energy in the refrigerant is now transferred to the atmosphere.

INTRODUCTION continued...

In order to understand Air Conditioning you must first understand heat. There are two types of heat that are controlled by an Air Conditioner (that is why it is called an air conditioner not just an air cooler).

Sensible Heat

Sensible Heat is the temperature of the air and this is the type of heat that is measured on a thermometer and what people think of when they hear the word.

Latent Heat

Latent Heat is the heat that is trapped in the moisture within the air (humidity), it is difficult to measure latent heat directly but it equates to 2265kJ per litre (you'd have to measure the water dribbling out of the drain). Air should be dehumidified to a Relative Humidity (RH) of 40-60%.

How well an A/C system removes both types of heat from the cabin of a vehicle is controlled by the design of the system. All systems are pretty good at removing the Sensible Heat but system design and operation play a big part in removing the Latent Heat.

- Variable Displacement Compressors (VDC) don't cycle completely off so they tend to work as a dehumidifier even when they are not 'cooling' the air
- Low blower fan speeds allow for more moisture to be drawn from the air as it passes over the evaporator
- Recirculating the air (especially in higher humidity climates) has a greater dehumidifying effect
- Many new cars with Auto Climate Control take advantage of all of the above, by employing VDC's, defaulting to a low blower speed and recirculation mode.

A/C SYSTEM CONFIGURATIONS

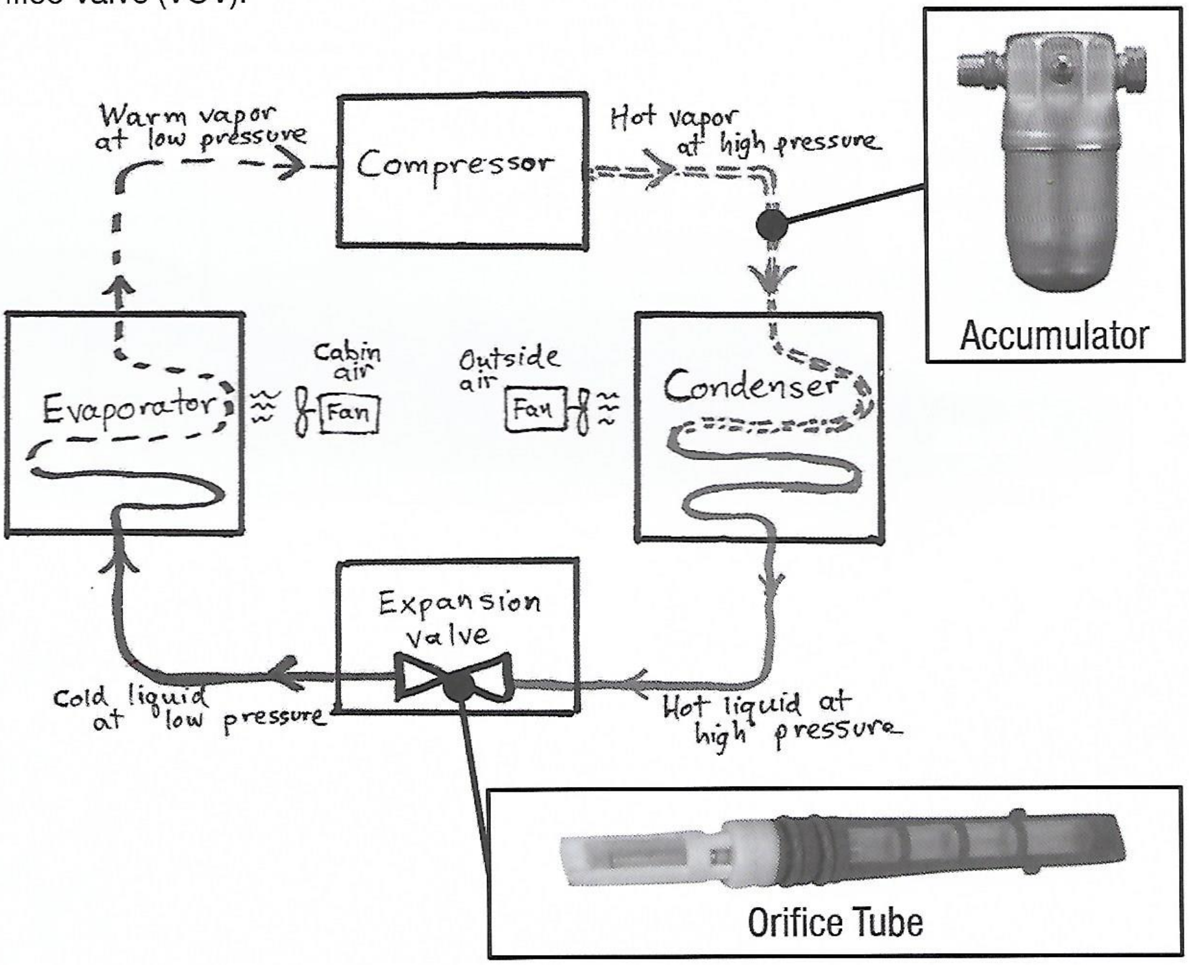
There are effectively two configurations:

- Orifice Tube and Accumulator
- Thermostatic Expansion (Tx) Valve and Receiver Drier

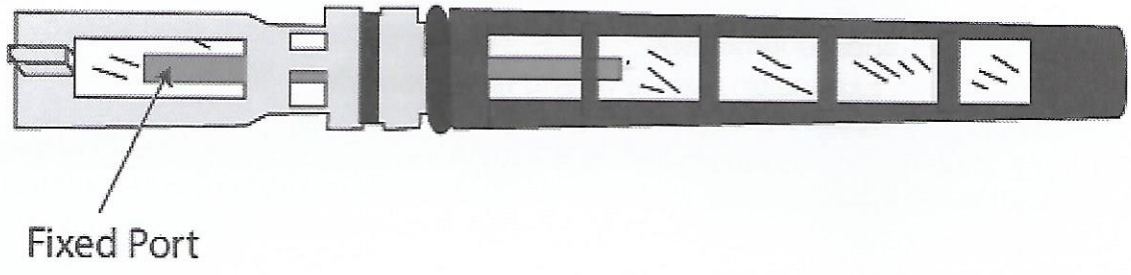
Regardless of the system configuration the expansion valve is always located at or prior to the inlet of the Evaporator.

Orifice Tube and Accumulator

The orifice tube is the expansion valve in these systems and many technicians are familiar with the Fixed Orifice Tube (FOT) but may not be aware of the Variable Orifice Valve (VOV).

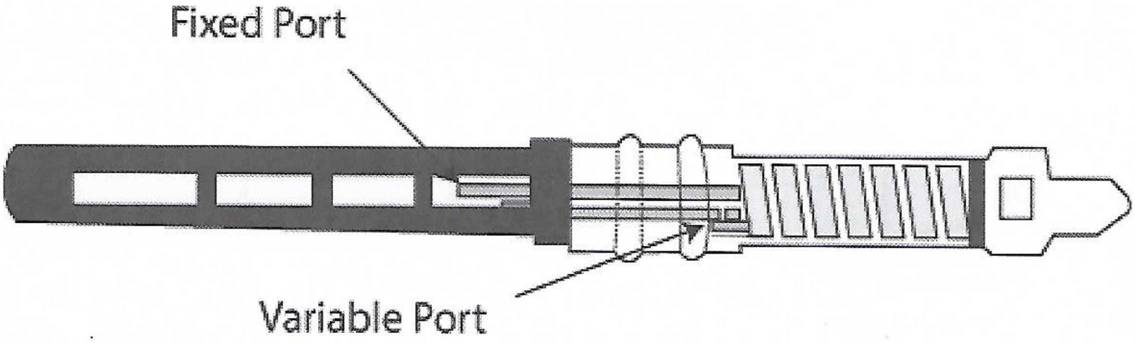

Warm vapor at low pressure
Compressor
Hot vapor at high pressure
Accumulator
Cabin air
Outside air
Evaporator
Fan
Fan
Condenser
Expansion valve
Cold liquid at low pressure
Hot liquid at high pressure
Orifice Tube

A/C SYSTEM CONFIGURATIONS continued...



Fixed Orifice Tubes are categorised by colour,			
1.19mm	Green	1.57mm	Red
1.35mm	Brown	1.70mm	Blue
1.45mm	Orange		Black

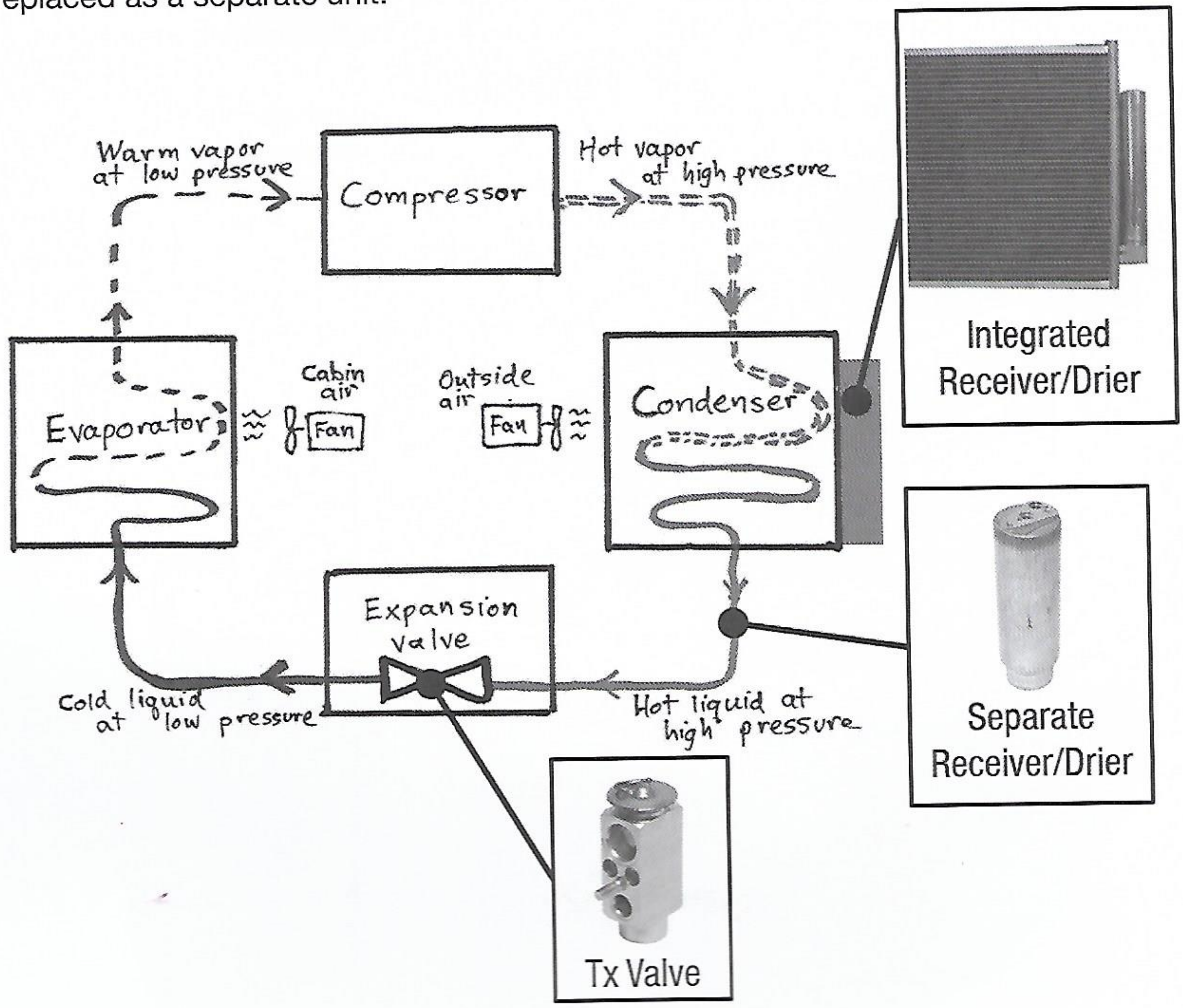
The VOV allows the A/C to control cooling rate dependant on the output of the A/C Compressor which is controlled by engine speed.



A/C SYSTEM CONFIGURATIONS continued...

Thermostatic Expansion (Tx) Valve and Receiver Drier

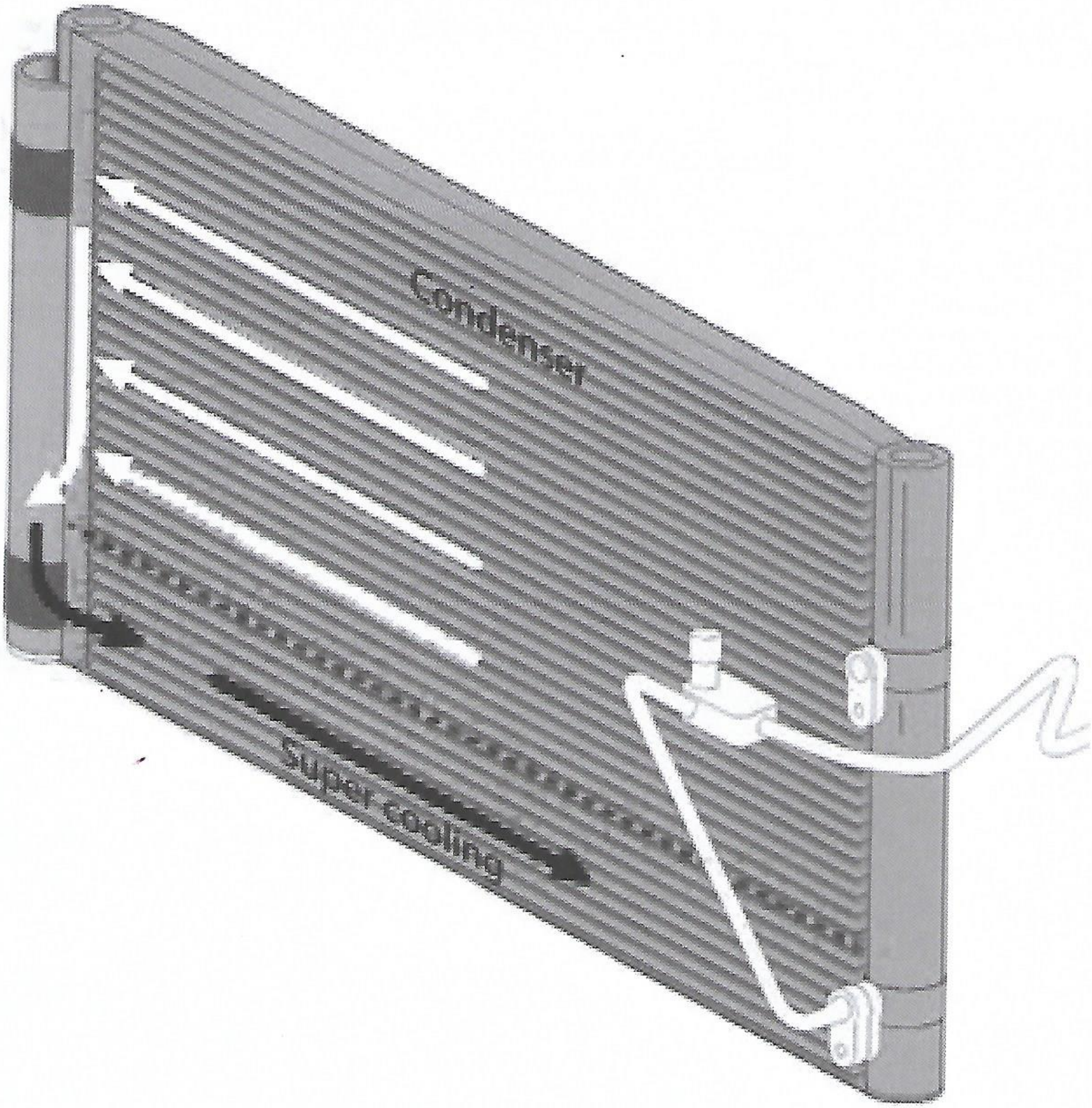
The Tx Valve with receiver drier is used on 90% of systems today. There are two types of receiver driers in use. Integrated systems are located at the A/C Condenser and have a replaceable Desiccant Bag, where traditional Receiver Driers are replaced as a separate unit.


Warm vapor at low pressure
Compressor
Hot vapor at high pressure
Integrated Receiver/Drier
Evaporator
Cabin air
Fan
Outside air
Fan
Condenser
Expansion valve
Separate Receiver/Drier
Cold liquid at low pressure
Hot liquid at high pressure
Tx Valve

A/C SYSTEM CONFIGURATIONS continued...

Integrated Receiver Driers

The current trend for Condensers with integrated Receiver Driers is not just about space and money saving for the manufacturer. The new condensers have the cooling area divided into two sections with the receiver drier between the two sections. Manufacturers claim a 30% greater efficiency for the same surface area.



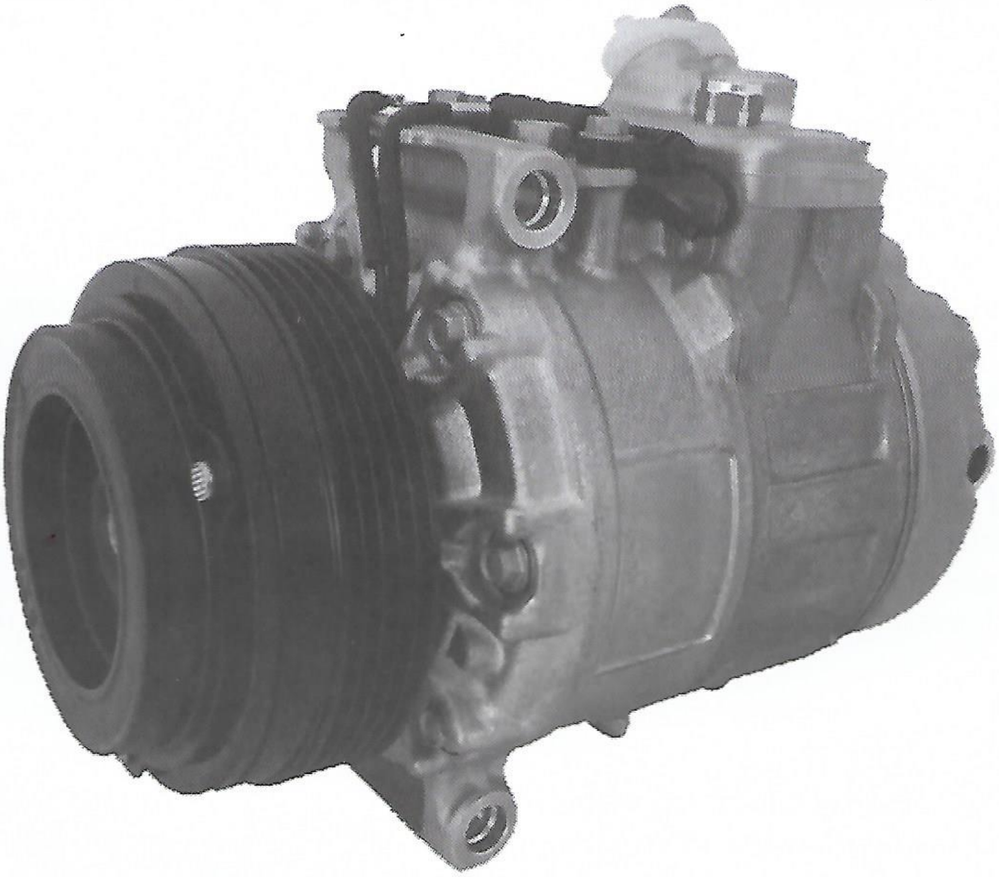
A/C SYSTEM CONFIGURATIONS continued...

Variable Displacement Compressors (VDC)

Overview
There are two type of VDC's:

1. Internally Controlled Variable Displacement Compressor's (ICVDC)
2. Externally Controlled Variable Displacement Compressor's (ECVDC)

All VDC's are more effective at removing Latent Heat, this provides a more comfortable cabin and therefore allows the thermostat temperature to be increased. This in turn lowers the demand on the compressor and therefore the energy consumed. As the compressor will run most of the time on less than 100% it uses less energy than a Cycling Clutch Compressor (CCC). VDC's ramp the compressor output up slowly (opposed to CCC's that cut in and out) this allows the drive belt size and tension to be reduced providing further energy saving advantages.



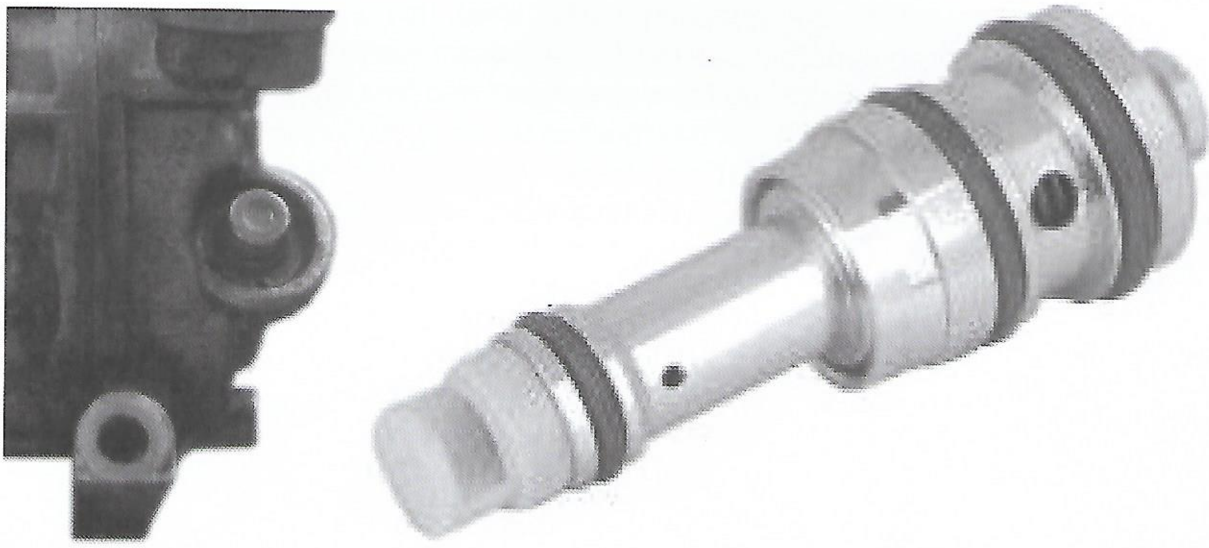
While all ICVDC's maintain a clutch to deactivate the system, most VDC systems do not employ a magnetic clutch, there are however some systems that do. So just because a vehicle has an A/C Compressor Clutch it doesn't mean that it is not a VDC. The VE Commodore is a popular vehicle that employs a clutch on the front of a VDC. Holden states that the clutch will disengage during full throttle acceleration, when engine speed is to high, when certain DTC's are logged, if engine temp is too high, if the ambient temp is too low or when refrigerant pressure is outside of parameters.

* If you Remove valve + it is coated with a black Residue comp. is stuffed.

A/C SYSTEM CONFIGURATIONS continued...

Mechanical Displacement Control Valves

A Variable Displacement Compressor (VDC) requires a control device. Early versions are referred to as Internally Controlled Variable Displacement Compressor's (ICVDC) and are controlled by a Mechanical Displacement Control Valve that is located on the compressor. The valve reacts to the differential pressure in the compressor that is representative of load. The greater the load sensed the greater the compressor displacement.



The mechanical displacement control valve is located with a circlip at the back of the compressor.

The Mechanical Displacement Control Valve's are prone to a particular failure. When the car is idling the A/C operating pressures are normal and the A/C is cold at the vents. When the engine speed increases the pressures equalise as if the compressor clutch has disengaged but that is not the case. The fault here is a bellows within the control valve has cracked/split. Some of the Mechanical Displacement Control Valve's are available through A/C parts suppliers in Australia so check availability before condemning the compressor.

- Sensible Heat - Air temp.
- Latent Heat - Temp of moisture in Air
- modern Cars Default to Recirc. + flick to vent at a set time to clear CO_2 etc in cab.
- must use scan Data as a Guide as it processed Data.

A/C SYSTEM CONFIGURATIONS continued...

Electronic Displacement Control Valves

Externally Controlled Variable Displacement Compressor's (ECVDC) utilise an ECU controlled Electronic Displacement Control Valve. The ECU uses a pulse-width modulated (PWM) Duty Cycle to vary the compressors output.

The electronic displacement control valve is also located with a circlip at back the of the compressor.

Unlike their mechanical relatives the Electronic Displacement Control Valve's are very reliable and normally only fail if they become contaminated which is usually the result of a failing compressor.

If an Electronic Displacement Control Valve failure is suspected:

- Check the PWM Duty Cycle Command with Scan Tool
- Certain failures will log a DTC
- Check command waveform with oscilloscope
- Measure resistance of winding with a multimeter (ohms)
- Mechanical failure will only be able to be identified by monitoring the amperage draw.

Caution: *This procedure if for diagnostic purposes only and Auto-Tech recommends faulty valves are only replaced if the compressor is known to be in good working order!*

Note: *It is important to keep in mind that in a Cycling Clutch Compressor (CCC) system the Tx Valve is the only device that controls pressure.*

On VDC systems both the Tx Valve and the Displacement Control Valve effect pressure!

A/C SYSTEM CONFIGURATIONS continued...

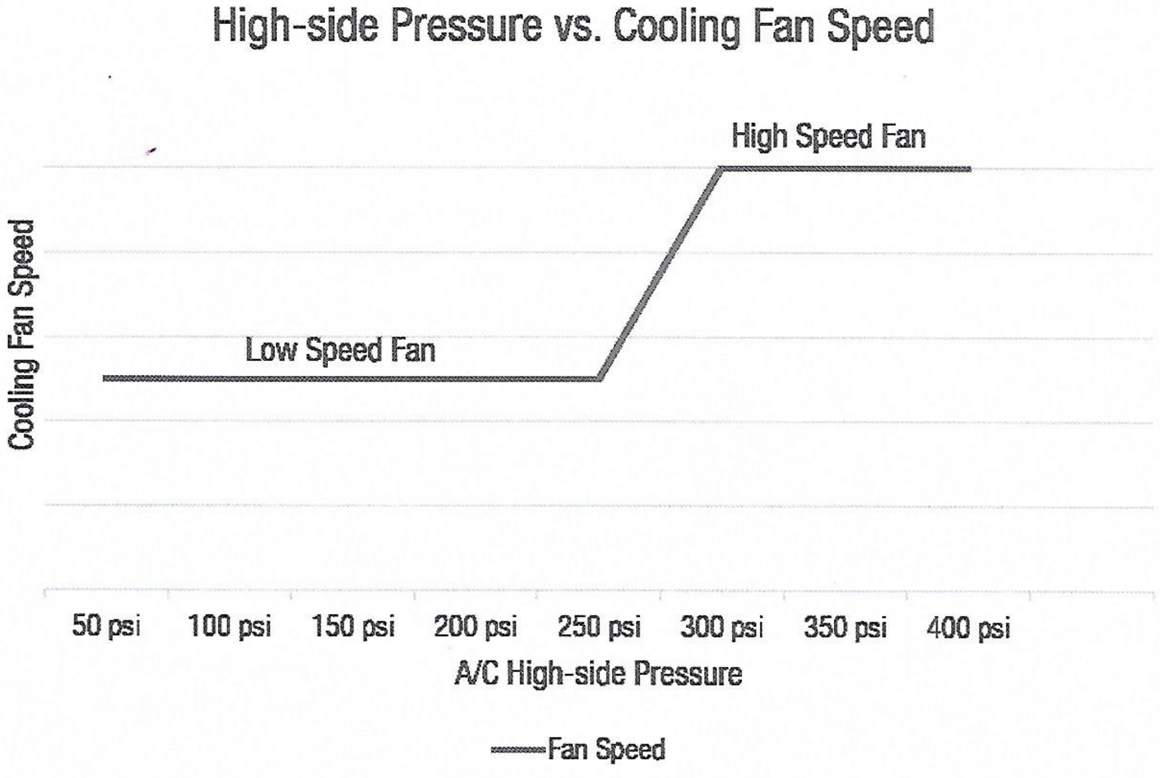
Cooling Fans

Once upon a time there was a distinction between then engine cooling fan and the A/C Condenser Fan/s. Today most vehicles have one or two electric cooling fans controlled by the Engine ECU with an input from the HVAC ECU to command the operation of the fan/s based on the high-side pressure. This information is helpful in understanding the operation of the cooling fans as during service and diagnosis.

Most vehicles are now utilising variable speed control, this will either be in the form of a two speed system or a full variable speed system. As the high-side pressure increases the fan speed (air flow volume) increases.

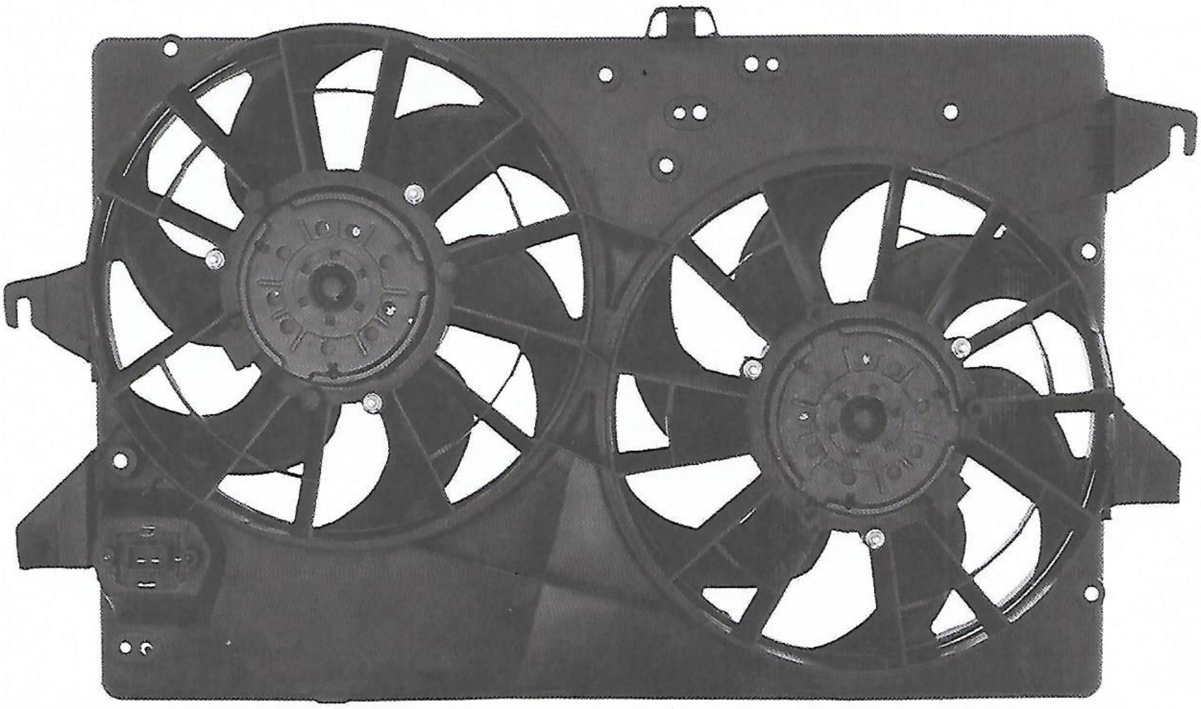
In warm ambient temperatures especially above 30°C the cooling fans have a big effect on high-side pressure, especially when the fans are not functioning properly.

Note: *Examples of two speed fan systems with an inoperative low speed function will often see high-side pressure reaching 300 psi before the fan/s cut in and the pressure drops to around 200 psi. The high-speed fan then cuts out and the whole cycle repeats, over and over...*

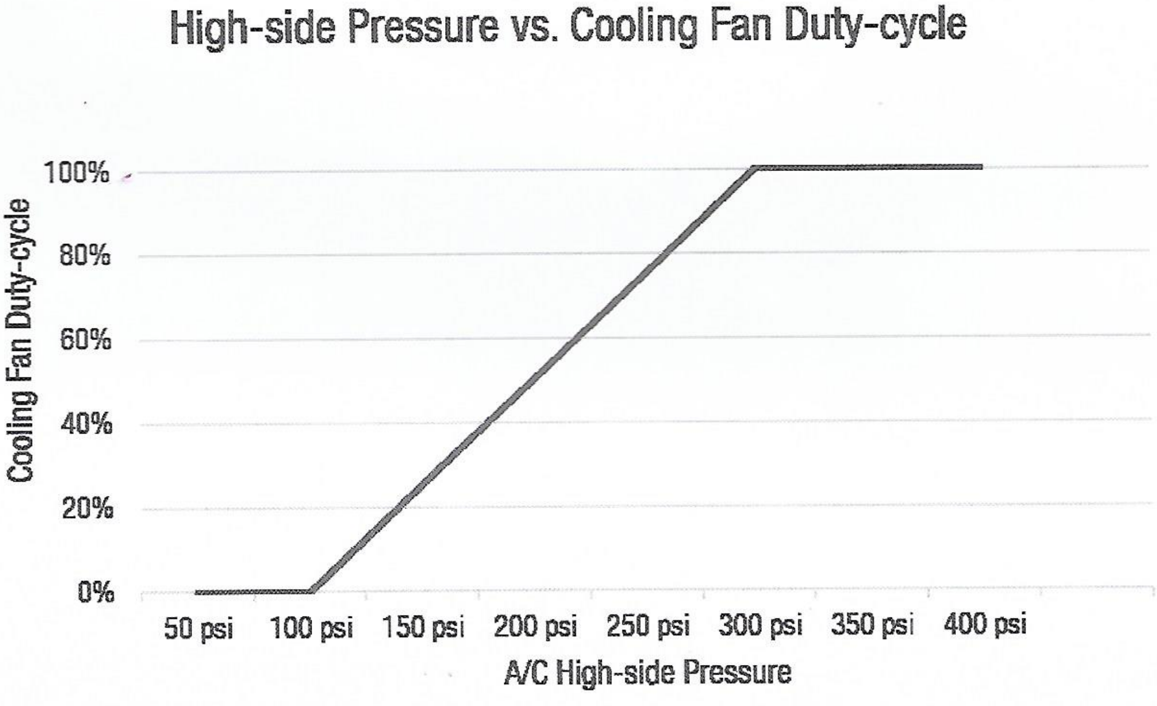


On a vehicle with a two speed cooling fan the low speed fan is often triggered by the switching on of the A/C and the high speed fan will be triggered around the 300psi range.

A/C SYSTEM CONFIGURATIONS continued...



Example of a typical cooling fan arrangement for a modern vehicle



Variable speed cooling fan systems will often start with no cooling fan operation until they reach a preset pressure (100 psi in this example). The duty cycle will then ramp up incrementally until full speed (100% Duty Cycle) is initiated around 300 psi

OIL TYPES

Polyalkylene glycol (PAG) Approx 98% of cars.

Polyalkylene glycol (PAG) oils are used in most R134a systems, there are a variety of different viscosities and blends. PAG oil is required for all R1234yf systems.

Polyolester (POE) must not use PAG in Hybrid very Important!!!

Ester oils were used in A/C systems that have been retrofitted from R12 to R134a. However, due to the high resistance to electrical flow they are now used for Hybrid/ Electric vehicles

Polyalphaolefin (PAO)

Is sold as a “Universal” oil and was originally developed for R22.

WARNING: *Auto-Tech and A/C Compressor manufacturers do not recommend the use of PAO "Universal" oils as they have been attributed to reduced performance, system contamination and compressor failure!*

Type	ISO	Gas	Denso	Sanden	Visc. 40°C	Visc. 100°C	App
PAG	46	R134a	ND8	SP-10	46	10	Typical
		R1234yf	ND12	SP-A2			
	68	R134a	-	SP-15	68	15	Specific
	100	R134a	ND9	SP-20	100	20	Typical
		R1234yf	-	-			Valeo
	150	R134a	-	-	150	30	Holden
POE	80	R134a & R1234yf	ND11	SE-10Y	80	10	Hybrid vehicles
PAO	N/A	Universal	N/A	N/A	Varies	Varies	☠

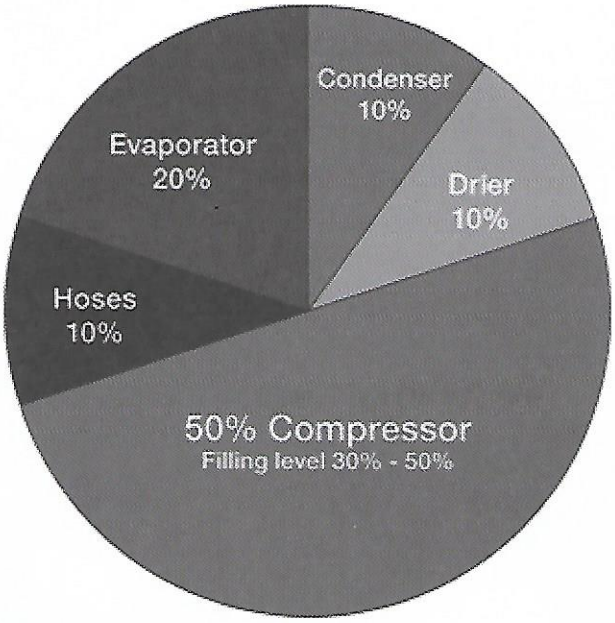
Caution: *If you put PAG oil in a hybrid/electric vehicle with an electrically driven compressor it will log a P0AA6 or P1C7C49 DTC and disable the A/C. The system will then require a full system flush and the compressor drained before recharging with the correct oil!*

* Important

OIL QUANTITY

When servicing an A/C system it is necessary to replace any oil that is lost during the process. If a system has had multiple component replacements over an extended period of time it may be difficult to ensure the correct amount is in the system.

- Too little oil will result in compressor overheating/failure
- Excessive oil will reduce A/C cooling performance
- Many OEM will provide specific oil quantities per component,if they do not use the following chart and/or table:



Note: *A good evacuation unit will include an oil trap so that the oil quantity that has been drawn out with the refrigerant can be calculated.*

Component	Oil Qty (ml)	Component	Oil Qty (ml)
Accumulator	≈40ml	Evaporator	≈30ml
Condenser	≈40ml	Hose (replace)	≈20ml
Compressor	see note	Hose (blown)	≈50ml
Desiccant Bag	≈20ml	Receiver/Drier	≈25ml

Note: *As the compressor is the major reservoir for the oil the quantity from the old compressor must be measured and the new compressor must be drained and have the same amount added as drained from the old component (plus 10-15%)!*

A/C REFRIGERANT PRESSURES

Over the years equipment has become more and more automated in an effort to reduce manual labour time and improve workshop productivity.

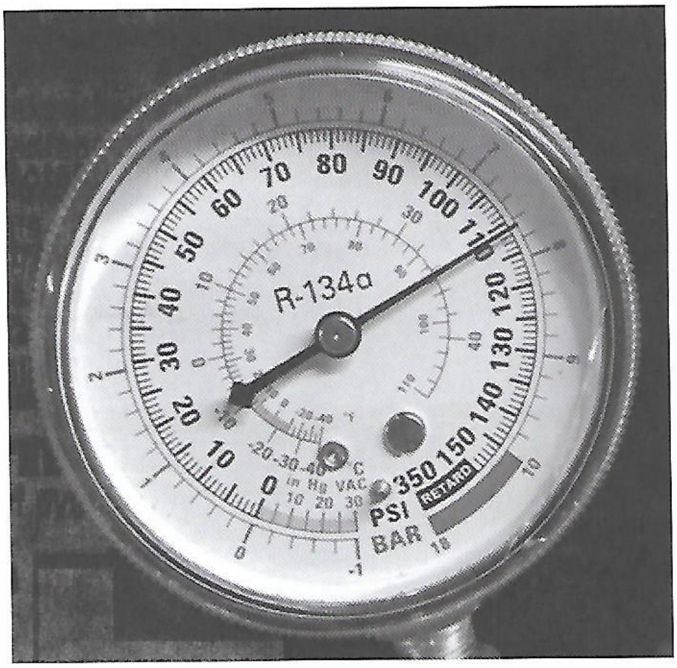
With A/C Systems there is a desirable refrigerant charge quantity that is measured by weight. But this charge quantity is based on a new vehicle. As a compressor wears it becomes less efficient and in order to achieve desirable cooling a customised charge quantity is required.

This customised charge is based on operating pressures, not charge quantity.

Static Pressures

1. Measure the ambient temperature
2. Measured with the A/C Compressor OFF
3. If no clutch on compressor pulley then must also have Engine OFF
4. Compare against Temperature vs Pressure chart
   (if you suspect that the gauge temp is not equal to ambient temp)

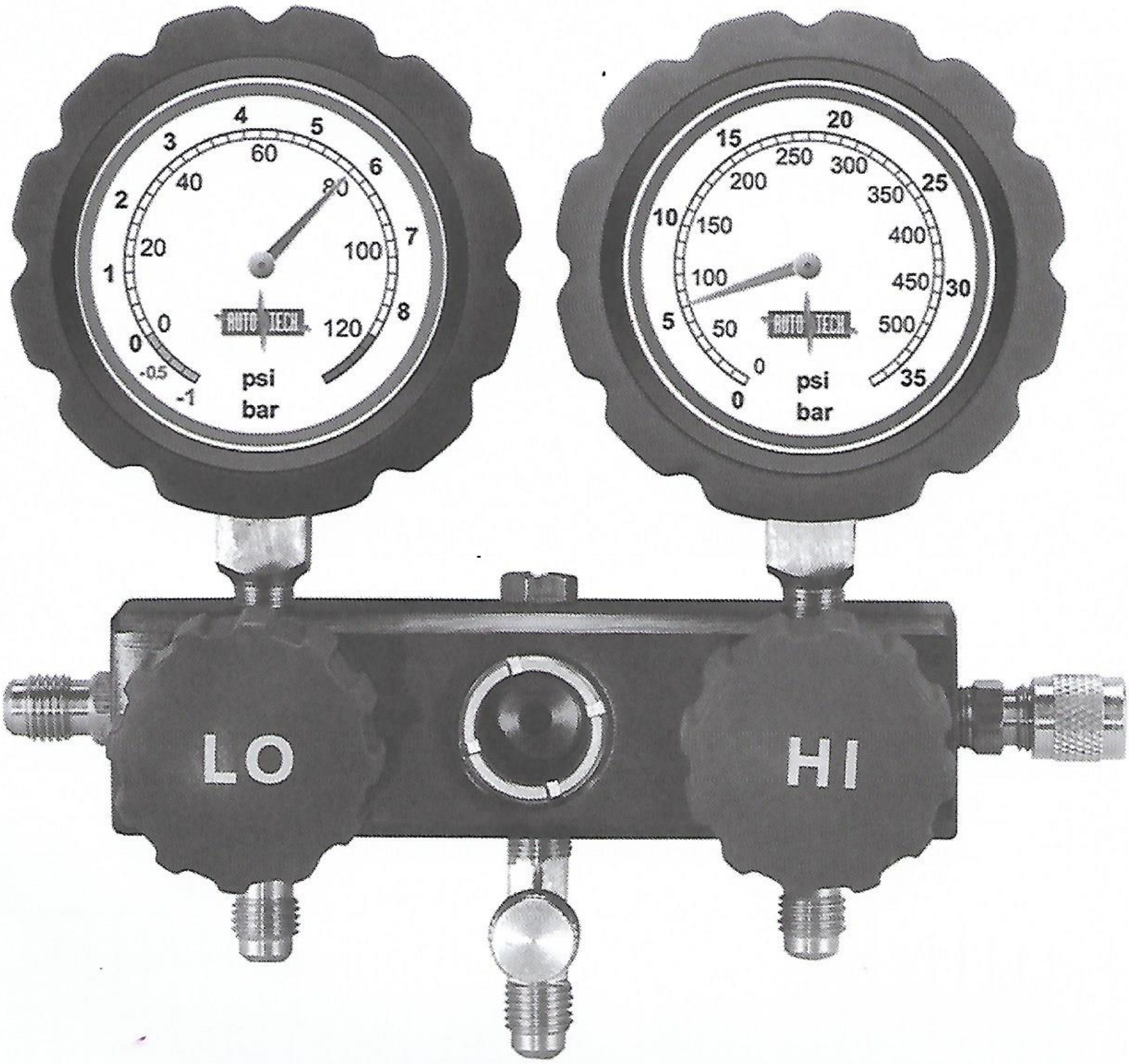
Most gauge sets include a conversion for refrigerant pressure to ambient temperature. This is usually found on the inner section of the dial face.



On these gauges the inner scale is an R134a temperature conversion, on this vehicle it is accurately displaying 34°C.

⚠ Caution: *Unlike running pressures that are influenced mainly by atmospheric temperature, static pressures are influenced by the refrigerant temperature, which will be effected by heat-soak. Check the temperature of the compressor with an infrared thermometer!*

A/C REFRIGERANT PRESSURES continued...



Typical Static Pressures @ 24°C

Temp.	A/C OFF	Temp.	A/C OFF
15°C	56psi	29°C	94psi
18°C	63psi	32°C	104psi
21°C	71psi	35°C	114psi
24°C	79psi	38°C	125psi
27°C	88psi	41°C	137psi

R134a Pressure vs Temperature Chart

A/C REFRIGERANT PRESSURES continued...

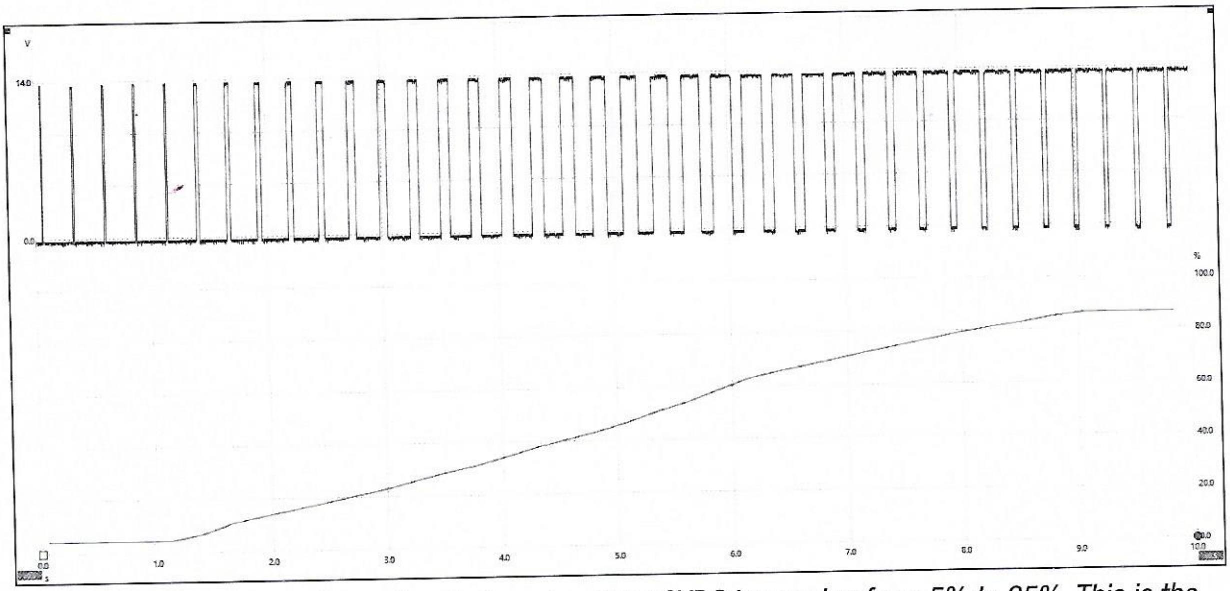
Normal Running Pressures

Preparation

1. Engine running
2. A/C on MAX Cold and MAX Fan Speed
3. Set direction to face vents
4. Open all doors
5. Allow the system to run in this state for at least 15 minutes
6. If the vehicle is fitted with a ECVDC use a scan tool to monitor the duty cycle of the electronic discharge control valve. It MUST remain in the 95-100% range for accurate pressure evaluation.
   If your scan tool does not display the A/C Compressor Command Value the ECVDC can be monitored using an oscilloscope or even a voltmeter.

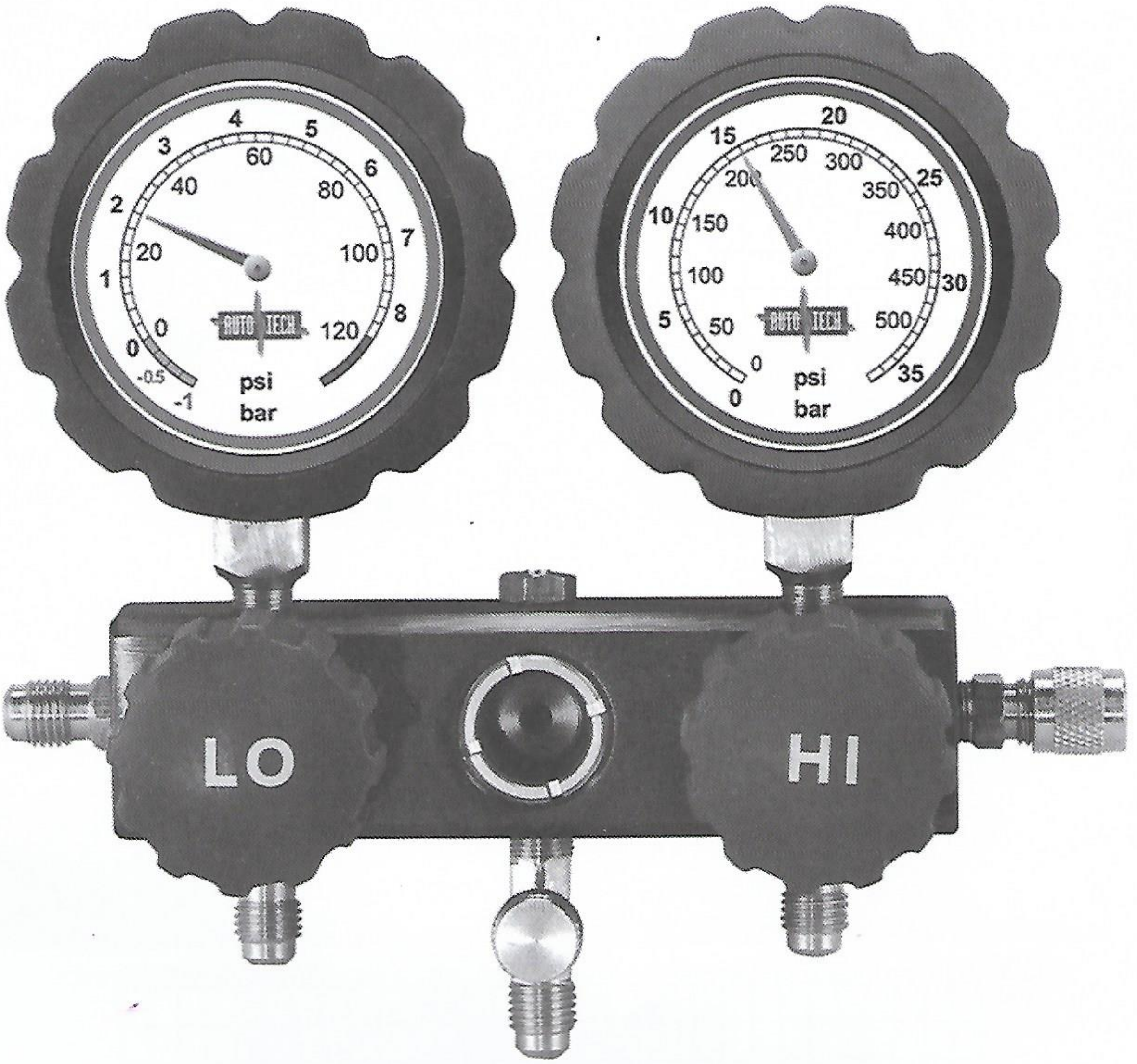
Duty Cycle to Average Voltage table for a 12 Volt A/C Compressor

Duty Cycle	Average Voltage	Duty Cycle	Average Voltage
10%	1.2-1.5 Volts	60%	7.2-8.9 Volts
20%	2.4-3.0 Volts	70%	8.4-10.4 Volts
30%	3.6-4.4 Volts	80%	9.6-11.8 Volts
40%	4.8-5.9 Volts	90%	10.8-13.3 Volts
50%	6.0-7.8 Volts	100% (Battery Volts)	12.0-14.8 Volts



The upper waveform shows the study cycle of an ECVDC increasing from 5% to 95%. This is the typical operating range. In the lower waveform a math channel has been used to graph the duty cycle, this is not a requirement but does provide an easy to interpolate output.

A/C REFRIGERANT PRESSURES continued...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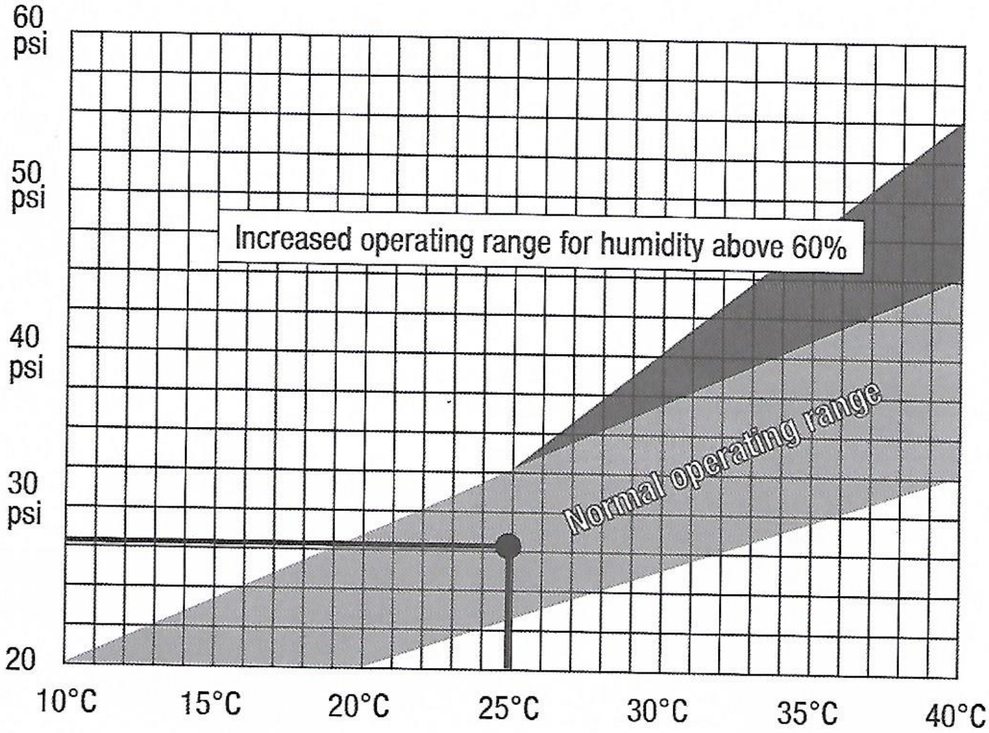
LO
HI

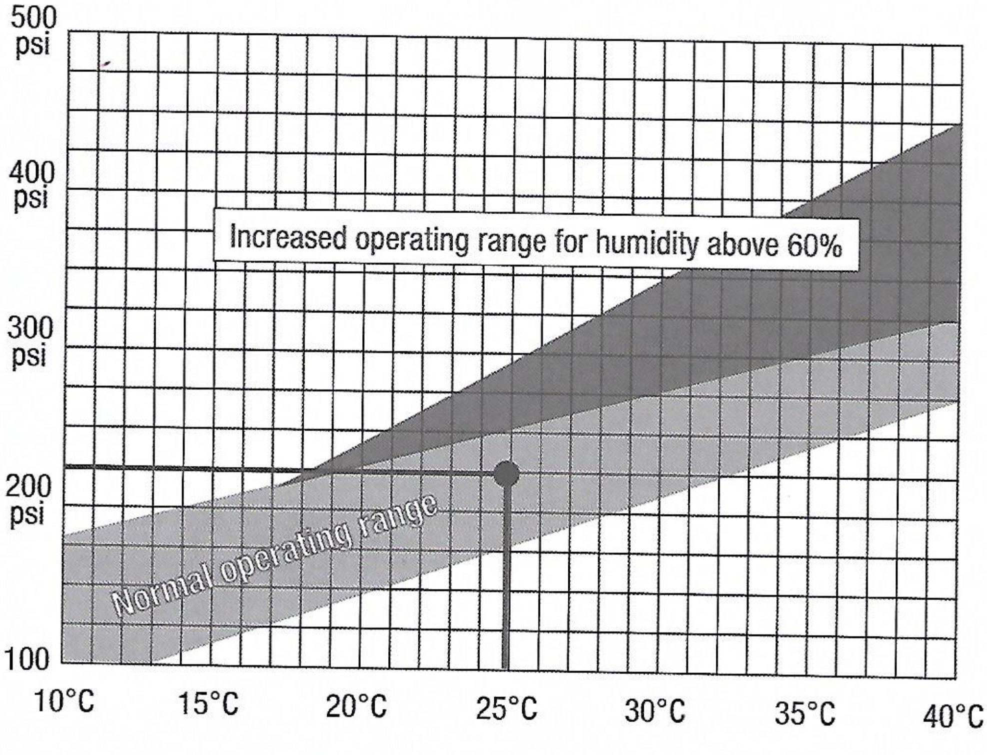
Typical Normal Running Pressures @ 24°C

A/C REFRIGERANT PRESSURES continued...

The following graphs provide the normal operating range of pressure relative to temperature and humidity. It is commonly understood that temperature effects pressure, but when you combine high temperature and high humidity it can force the pressures even higher, especially on the high side.



Low-side pressure versus temperature graph

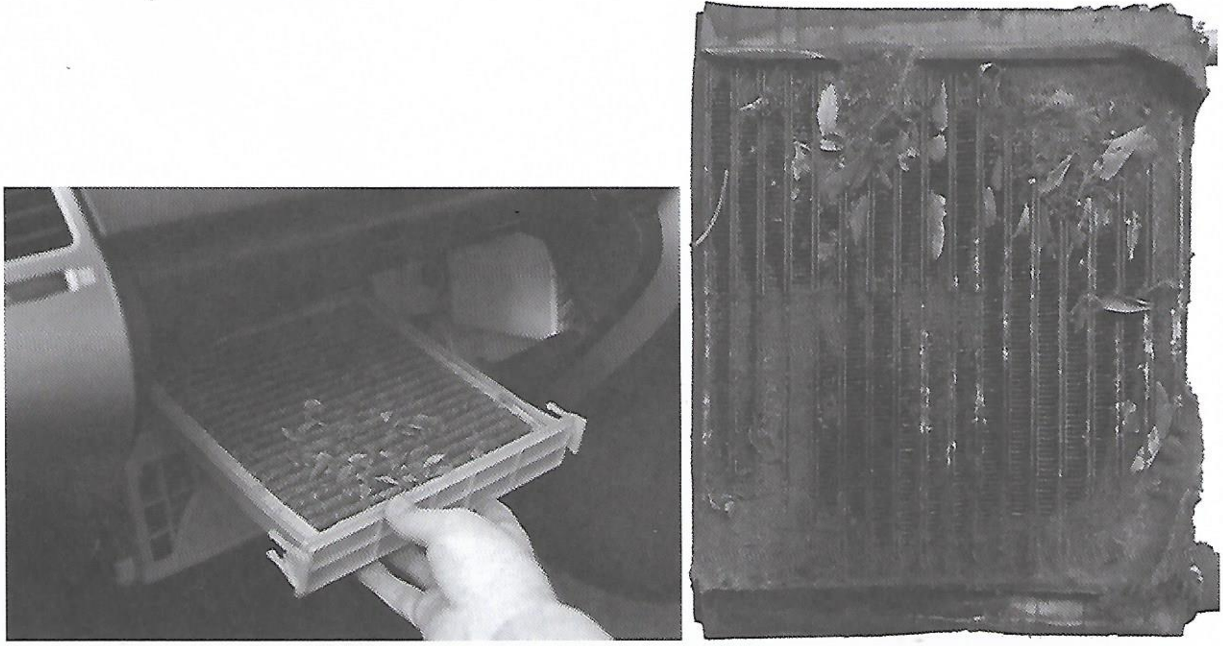


High-side pressure versus temperature graph

A/C REFRIGERANT PRESSURES continued...

Normal Running Pressures – Poor or No Cooling

- A/C – Heater blend door not closing completely
- Heater tap faulty (if fitted)
- Blocked Cabin Filter
- Evaporator blocked with lint, dirt, etc…
- Faulty thermistor, check that A/C is not cycling in and out (or displacement control valve duty cycle if VDC)
- Slipping compressor clutch (if fitted)
- Evaporator frozen



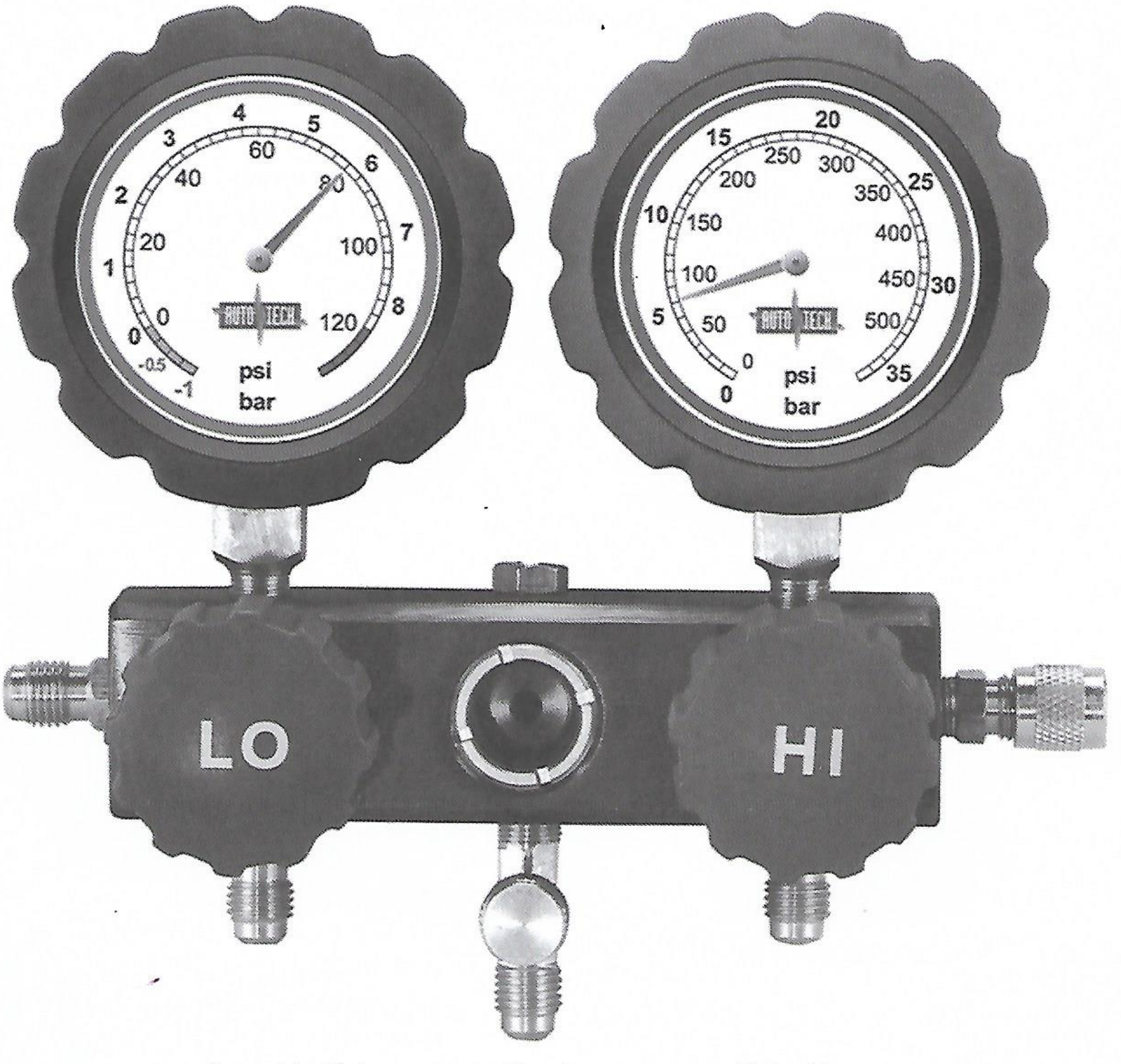
Poor maintenance of the cabin filter (left) leads to contamination of the evaporator (right) resulting in poor A/C efficiency.

Note: *Poor cabin filter maintenance can lead to expensive evaporator repairs. Using the RECIRC function reduces pollutants. Many cars default back to RECIRC every key cycle to reduce evaporator contamination!*

Also check that the RECIRC Door is not faulty and stuck on FRESH!

A/C REFRIGERANT PRESSURES continued...

Low-side High - High-side Low

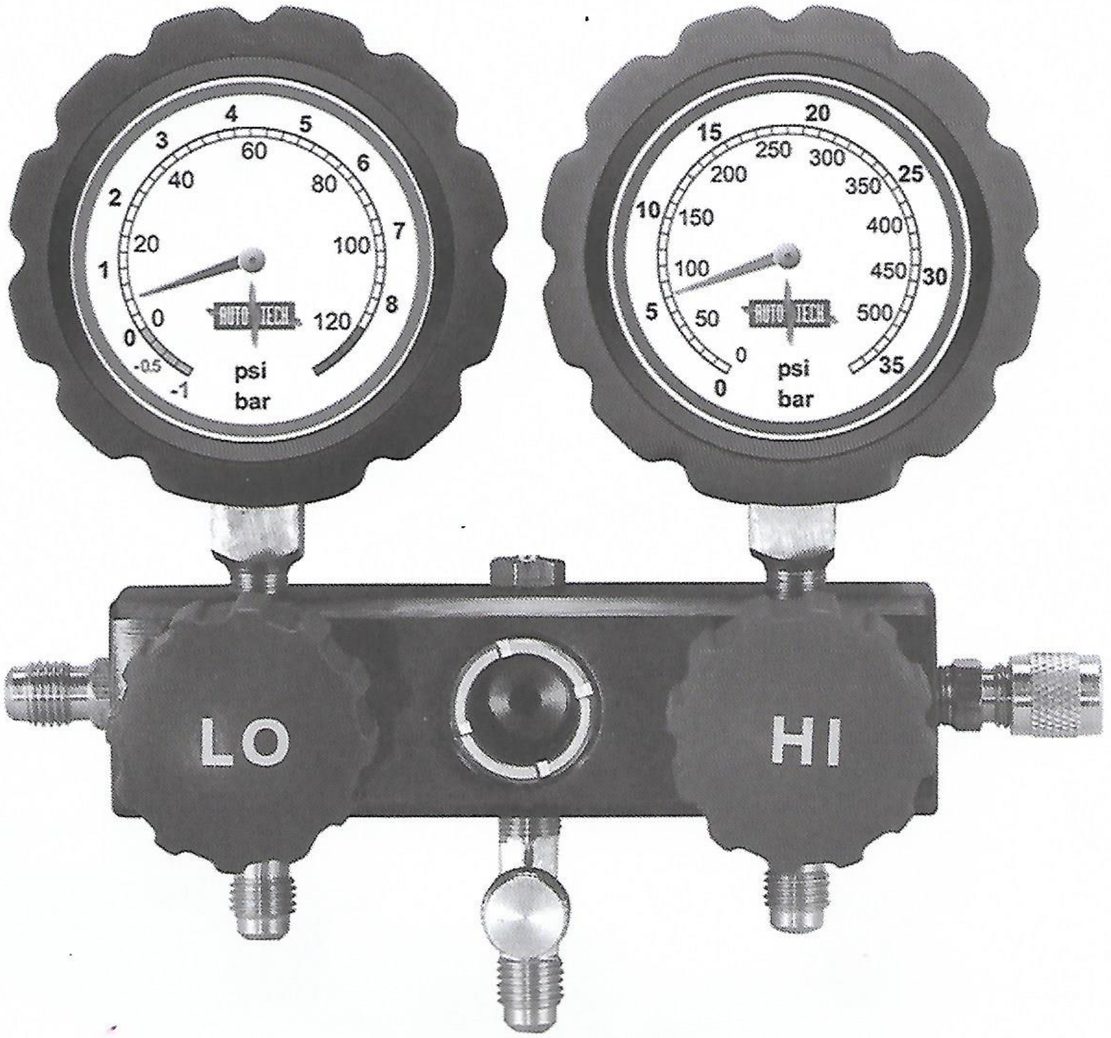


Low-side High *< Equal >* *High-side Low*

1. Compressor clutch NOT engaged (if fitted)
2. No drive belt (but I hope you checked that before this point...)
3. Displacement control solenoid on minimum (VDC ONLY)
4. Internal compressor failure

A/C REFRIGERANT PRESSURES continued...

Low-side Low - High-side Low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Low-side Low *High-side Low*

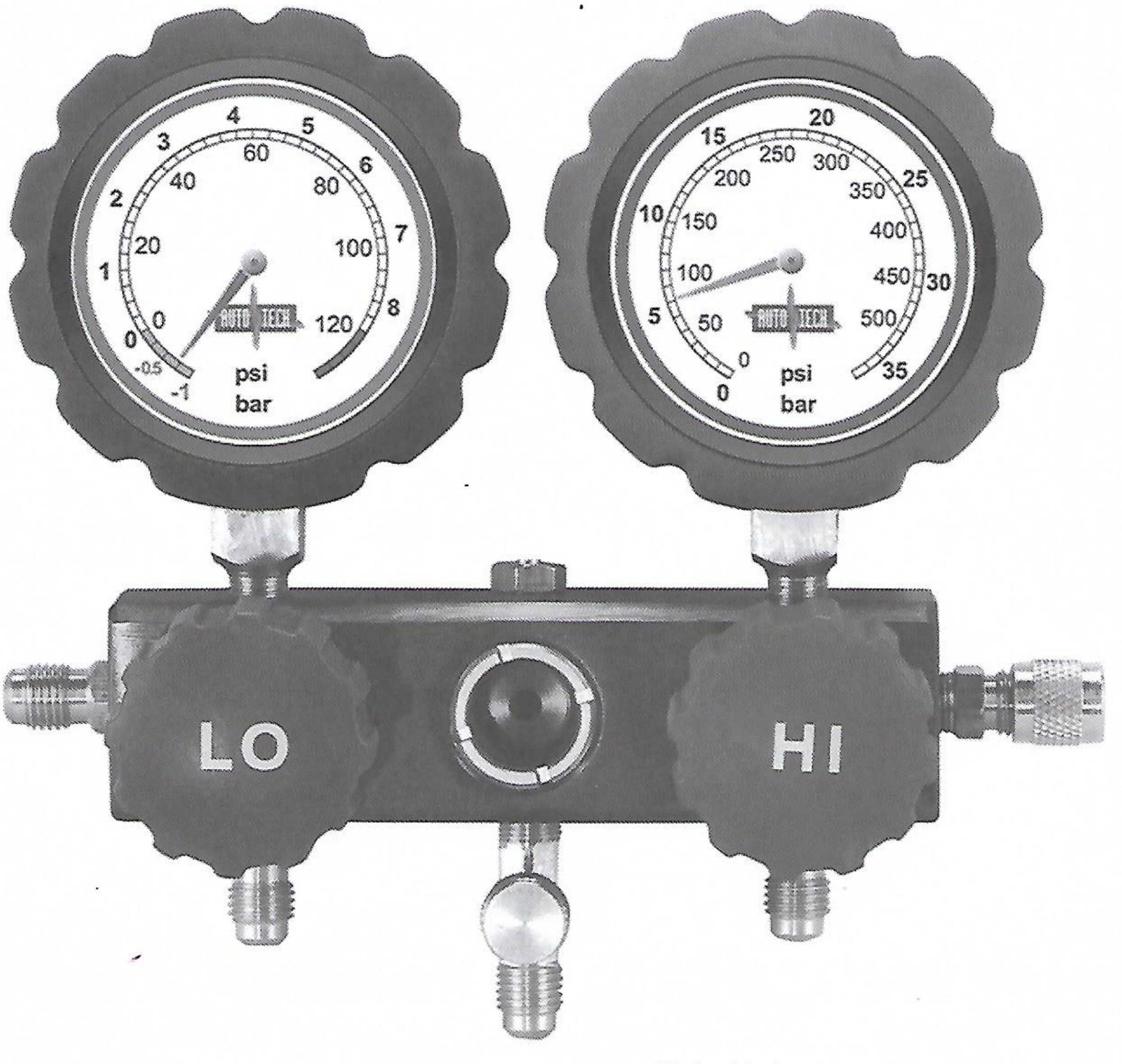
1. Very low ambient temperature
   Is it actually normal? Check the temperature to pressure chart
2. Low refrigerant charge
3. Restriction between compressor and High Pressure Service Port
   It is not uncommon to find a damaged pipe due to impacts as it includes the entire condenser located in front of the radiator
4. Expansion Valve restricted, partially blocked
5. Restriction between High Pressure Service Port and evaporator (VDC ONLY)

Caution: *Do not "Top-up" a system with a suspected low charge. If the cause is a blocked or faulty Tx Valve it could result in the compressor overheating!*

If the Tx Valve is restricted the system will be starved of refrigerant and the lubrication that is carried by it, resulting in overheating and catastrophic compressor failure!

A/C REFRIGERANT PRESSURES continued...

Low-side Negative - High-side Low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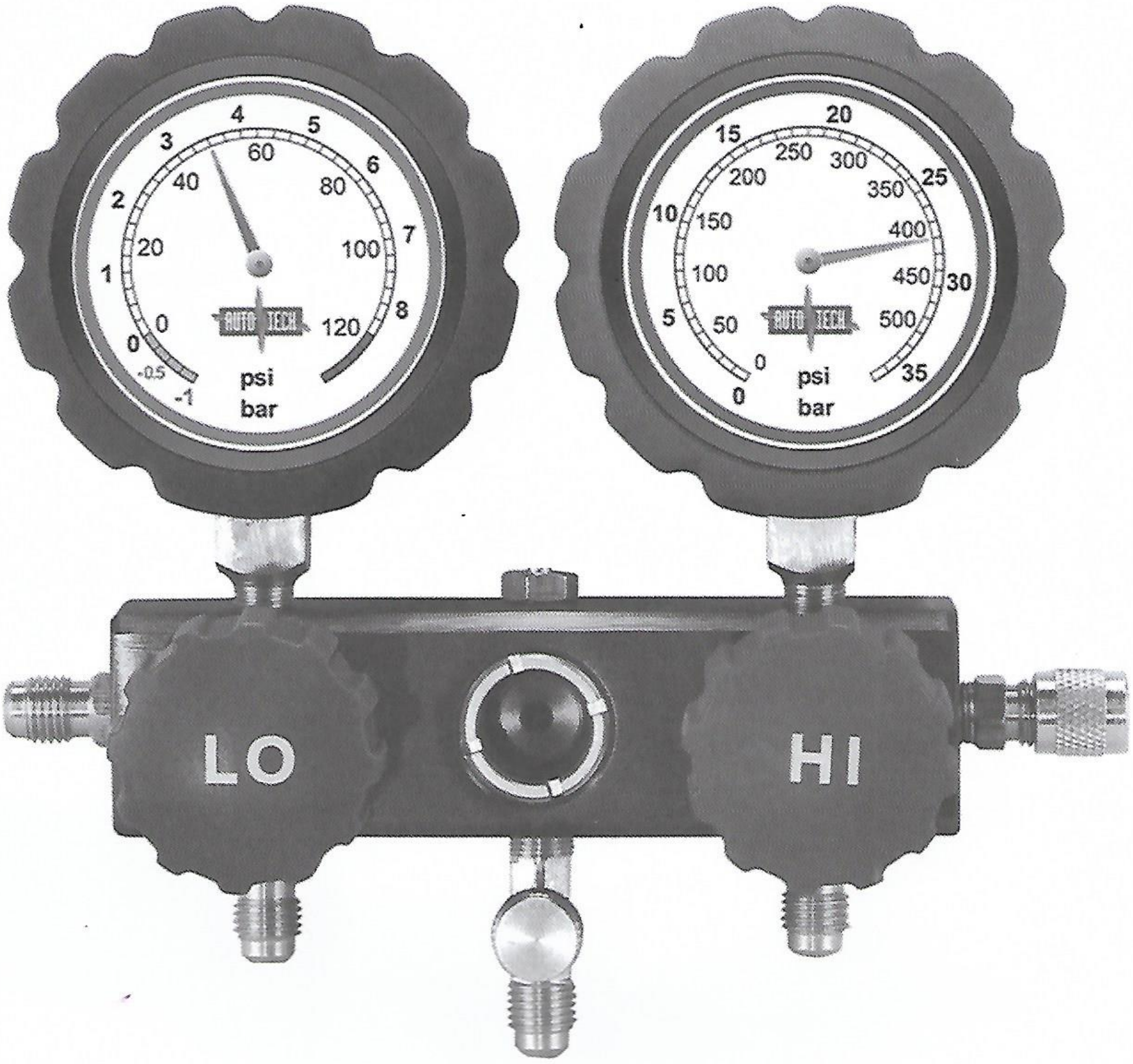
Low-side Negative *High-side Low*

1. Expansion Valve blocked

⚠ Caution: *If the Tx Valve is restricted the system will be starved of refrigerant and the lubrication that is carried by it, resulting in severe overheating of the compressor and can lead to catastrophic failure!*

A/C REFRIGERANT PRESSURES continued...

Low-side High - High-side High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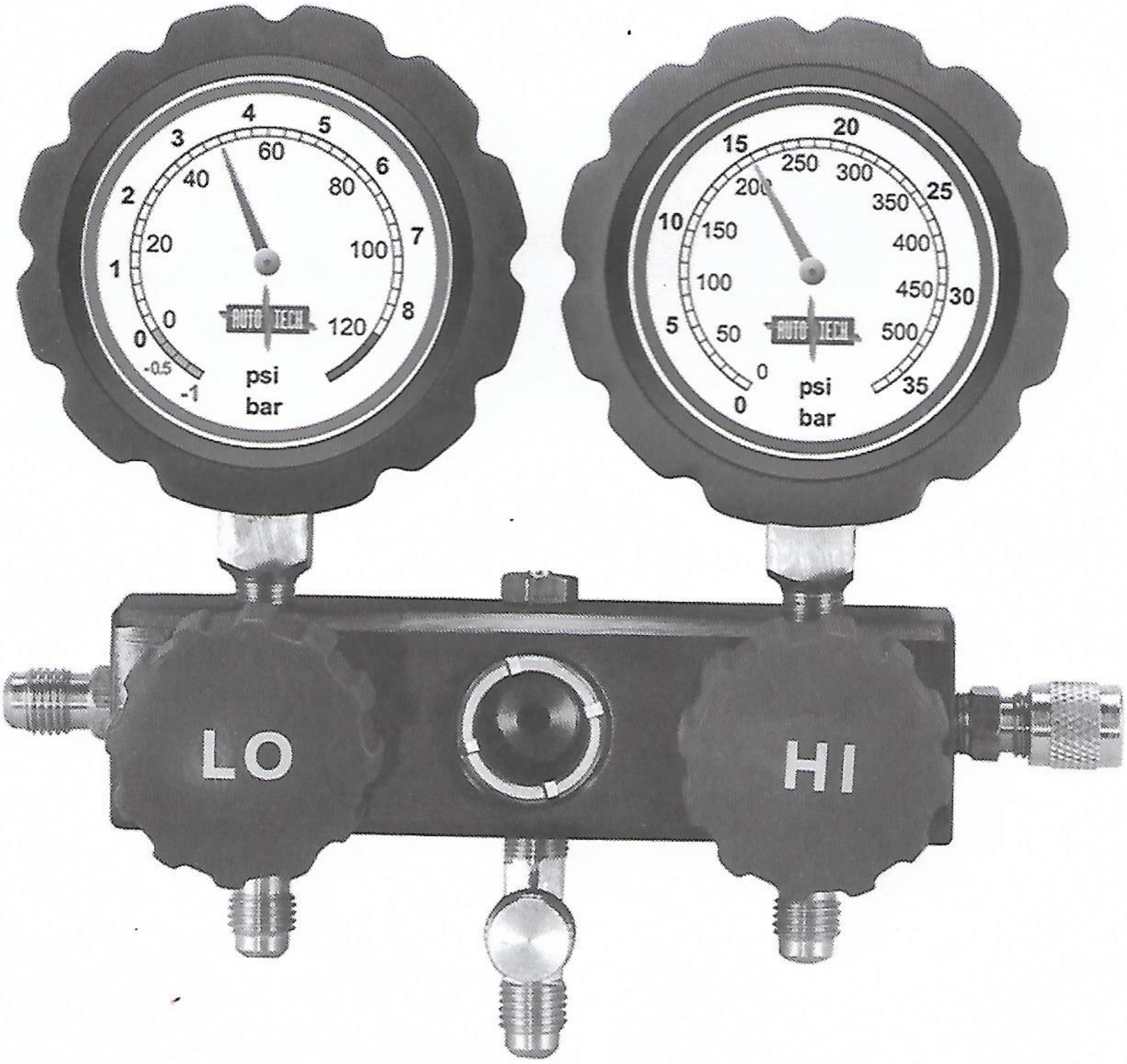
Low-side High *High-side High*

1. Very high ambient temperature/humidity
   Is it actually normal? Check the temperature to pressure chart
2. Refrigerant over-charged
3. Air in system (improperly evacuated last service)
4. Displacement control solenoid on maximum (VDC ONLY)
5. Restriction between high-side service port and evaporator
6. Inefficient condenser, check external contamination & condenser fan
7. High engine operating temperature – Check cooling system

Note: *The Cooling Fans should be roaring at full speed due to the extreme high-side pressure. If not check the fan operation before continuing!*

A/C REFRIGERANT PRESSURES continued...

Low-side High - High-side Normal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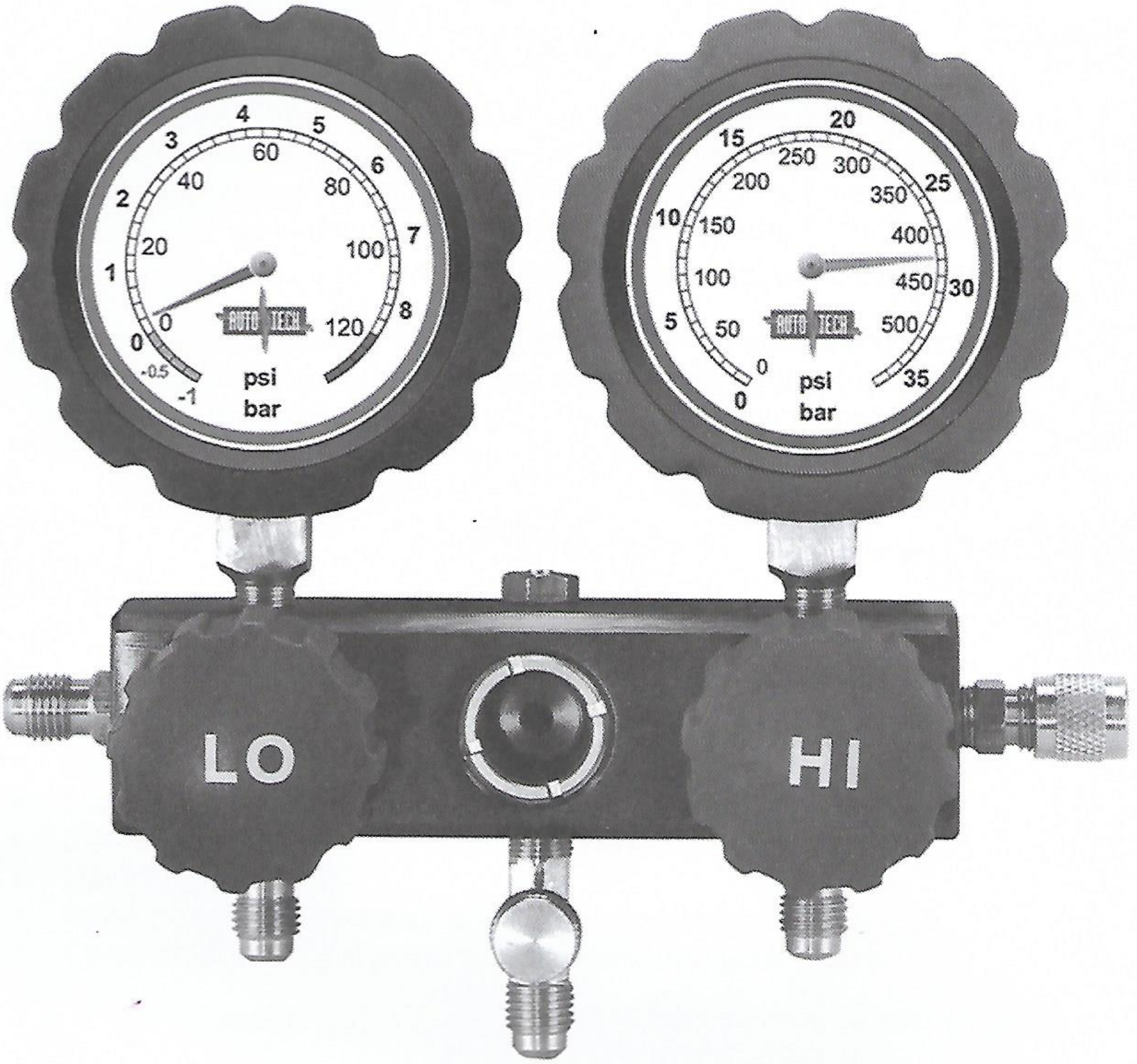
psi
bar
LO
HI

Low-side High *High-side Normal*

1. Expansion valve stuck open
2. Displacement control solenoid faulty (VDC ONLY)
3. Compressor worn

A/C REFRIGERANT PRESSURES continued...

Low-side Low - High-side High



Low-side Low *High-side High*

1. Filter saturated
2. Displacement control solenoid on maximum (VDC ONLY)
3. Restriction between Receiver/Drier and Evaporator
   (look for condensation or frost to identify point of restriction)

Note: *The Cooling Fans should be roaring at full speed due to the extreme high-side pressure. If not check the fan operation before continuing!*

REFRIGERANT CHARGING

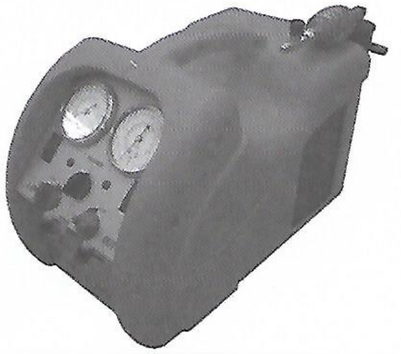
Before discussing the best charging procedure for A/C Systems it is essential to address the preparation requirements:

Topping Up

Do not top up systems, as discussed in the A/C Refrigerant Pressures topic there are a number of other issues with the same symptoms as a low charge and an overcharged system can lead to overheating and compressor failure. Not to mention the risk of the charge simply leaking into the atmosphere.

Evacuation

In a busy workshop and at peak A/C service times (first hot weeks of summer) there is pressure to reduce the time each vehicle spends on the A/C Charging Station. Insufficient evacuation reduces the A/C effifiecy and can lead to poor customer experiences. Each vehicle MUST have 30 minutes at -27"Hg (-100kPa). Only at this vacuum can the moisture from the atmosphere be boiled off and evacuated.



If job turnover is limiting the time a vehicle spends on evacuation, consider using an additional stand alone Evacuation Unit.

Receiver Drier or Desiccant Bag Replacement

- Has the system been open to the atmosphere for more than 5 minutes?
- Was the system in a state of very low charge before service?
- Has it been more than 2 years since the last service?
- Was a component replaced due to a blockage or contamination?
- Was the compressor replaced?

If you answered YES to ANY of the above questions, the Receiver Drier or Desiccant Bag MUST be replaced.

REFRIGERANT CHARGING continued...

Over the years equipment has become more and more automated in an effort to reduce manual labour time and improve workshop productivity.

With A/C Systems there is a desirable refrigerant charge quantity that is measured by weight. But this charge quantity is based on a new vehicle. As a compressor wears it becomes less efficient and in order to achieve desirable cooling a customised charge quantity is required.

This customised charge is based on operating pressures, not charge quantity.

Step 1
Carry out repairs and prepare the system (including evacuation)

Step 2
Set the charging scales to zero, then draw in as much refrigerant as possible with the engine OFF.

Step 3

- Take note of the Ambient Temperature
- Start the engine
- Turn the A/C to MAX COLD
- Blower Fan on HIGH
- Mode set to FRESH
- Direction set to FACE
- Open all Dash Vents
- Insert vent thermometer
- Open all windows

⚠ *Caution:* *A/C Charging should always be performed in a shaded and well ventilated area!*

Step 4
Take the refrigerant level up to 80% of the recommended charge quantity. This will be enough for the system to operate with enough refrigerant and oil flow so that no damage will occur and should also produce reasonable cooling efficiency

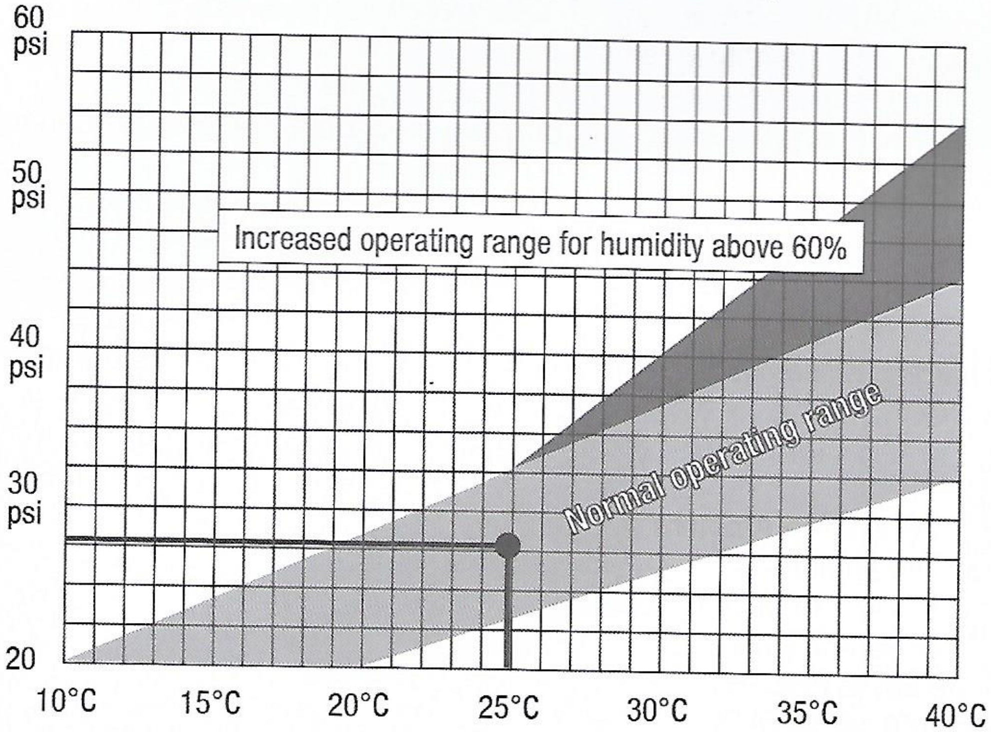
ℹ *Note:* *For R134a systems it is usually at around the 80% mark that the bubbles will disappear from the sight glass (if fitted).*

Step 5
Allow the vehicle to idle in the above condition for 15 minutes

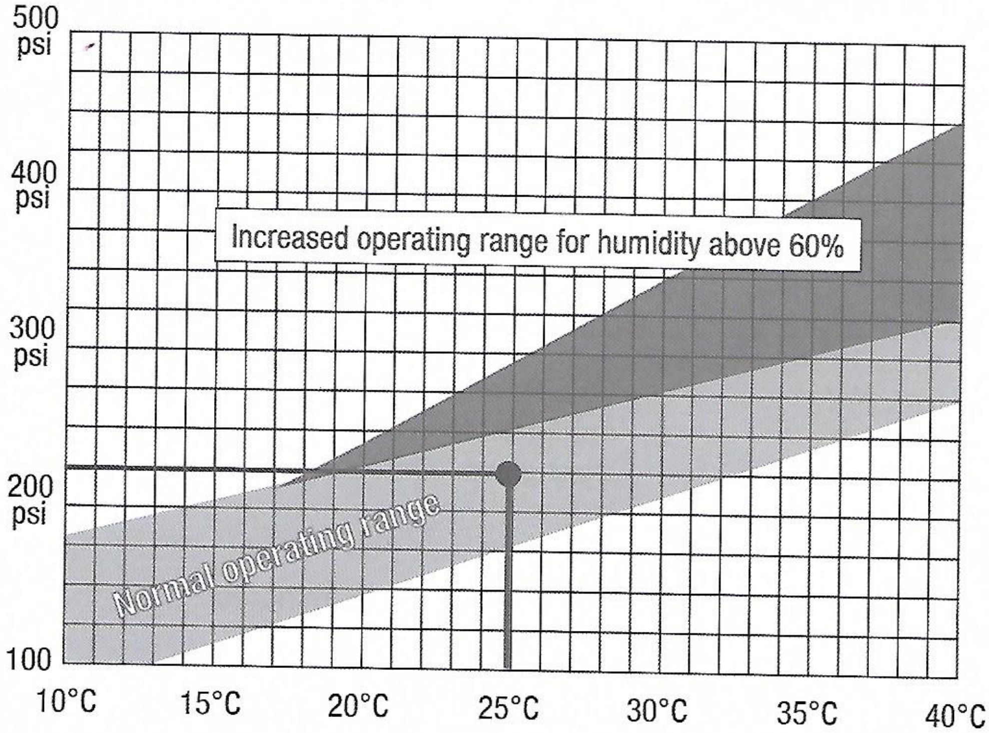
REFRIGERANT CHARGING continued...

Step 6

Using gauge pressures as your priority increase the charge quantity until the optimal pressures are achieved for the ambient temperature. The charge quantity (by weight) should be within the manufacturers specifications, but slight increase of up to 10% are acceptable as long as the pressures remain optimal.



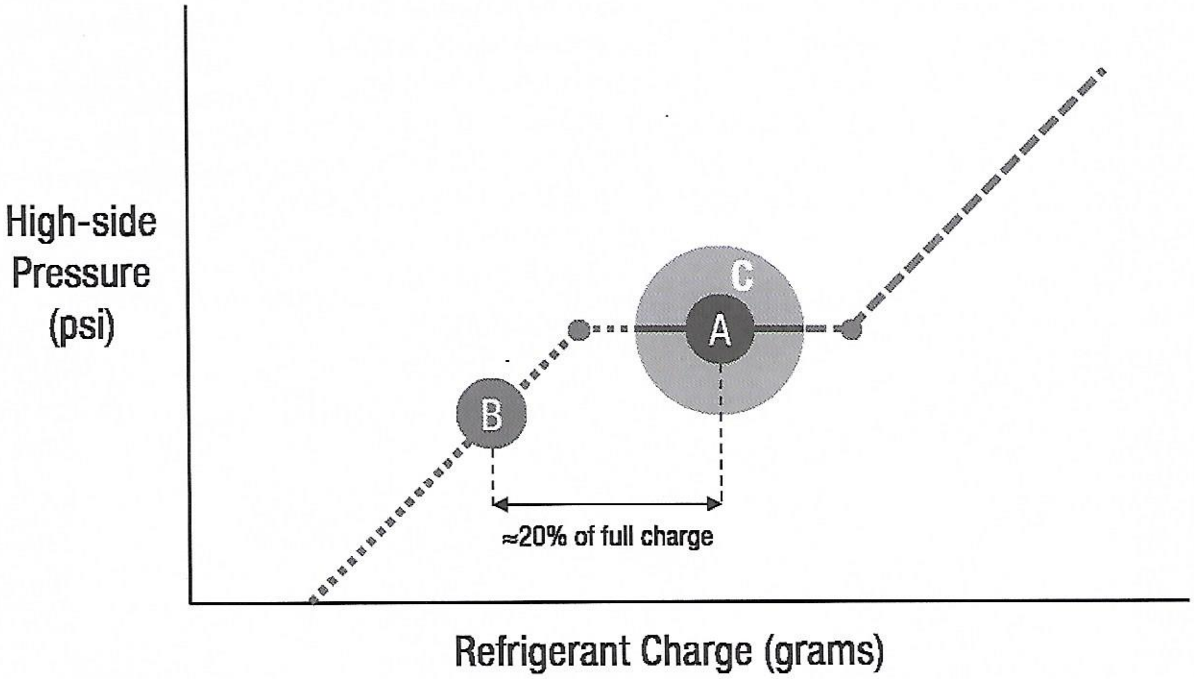
Low-side pressure versus temperature graph



High-side pressure versus temperature graph

REFRIGERANT CHARGING continued...

The following charge graph shows the relationship between charge quantity and high-side pressure. While there is an optimal range (A) there is a zone (C) where the charge quantity can be tweaked to improve low-side pressure without having adverse effects of the high-side pressure.



Item	Description
A	Standard Charge
B	Bubbles disappear from sight glass
C	Standard Charge ± 10%
▪▪▪▪▪▪▪▪▪▪▪▪▪▪	Undercharged
▬ ▬ ▬ ▬ ▬ ▬ ▬	Overcharged
━━━━━━━━	Optimal Charge

REFRIGERANT TYPES

From 2011 on, all **new model** vehicles in Europe must use a refrigerant with a Global Warming Potential (GWP) of less than 150 and by 2017 **all new vehicles** must meet this standard.

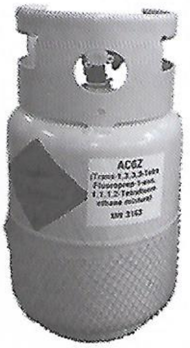
Note: *The EU Directive is not part of the vehicle emission standard (EURO VI) and does not apply to Australia.*

However, Australia has implemented the OPSGG Program as part of our commitment to the Montreal Protocol which came into effect on the 1st of January 2018.

The EU Directive does not state the type of gas required, just the GWP limit. There were 3 refrigerants under investigation:

R1234yf

R744



R445a (AC6)

R1234yf

Refrigerant R1234yf is a blend of gases technically called Hydro-Floro-Olefin 2,2,2,3 Tetrafluoropropene and has a GWP of 4. It is a completely different substance to R134a but it performs in a similar manner meaning that the traditional Air Conditioning (A/C) system only needs to be tweaked to suit the changes in pressure and cooling efficiency. It has now been accepted as the best option by all vehicle manufacturers and is now widely used.

R744

R744 is refrigerant grade CO2. While it is completely neutral to the atmosphere it requires very high operating pressures and early testing suggests that it will not perform well in extremely hot climates like those found throughout Australia. R744 works very well in reverse cycle heat pumps making it an excellent choice for Electric and Hybrid Electric vehicles as well as in extremely cold climates. The first production vehicle using R744 is the 2017MY Mercedes Benz S400 Coupe for the EU market only.

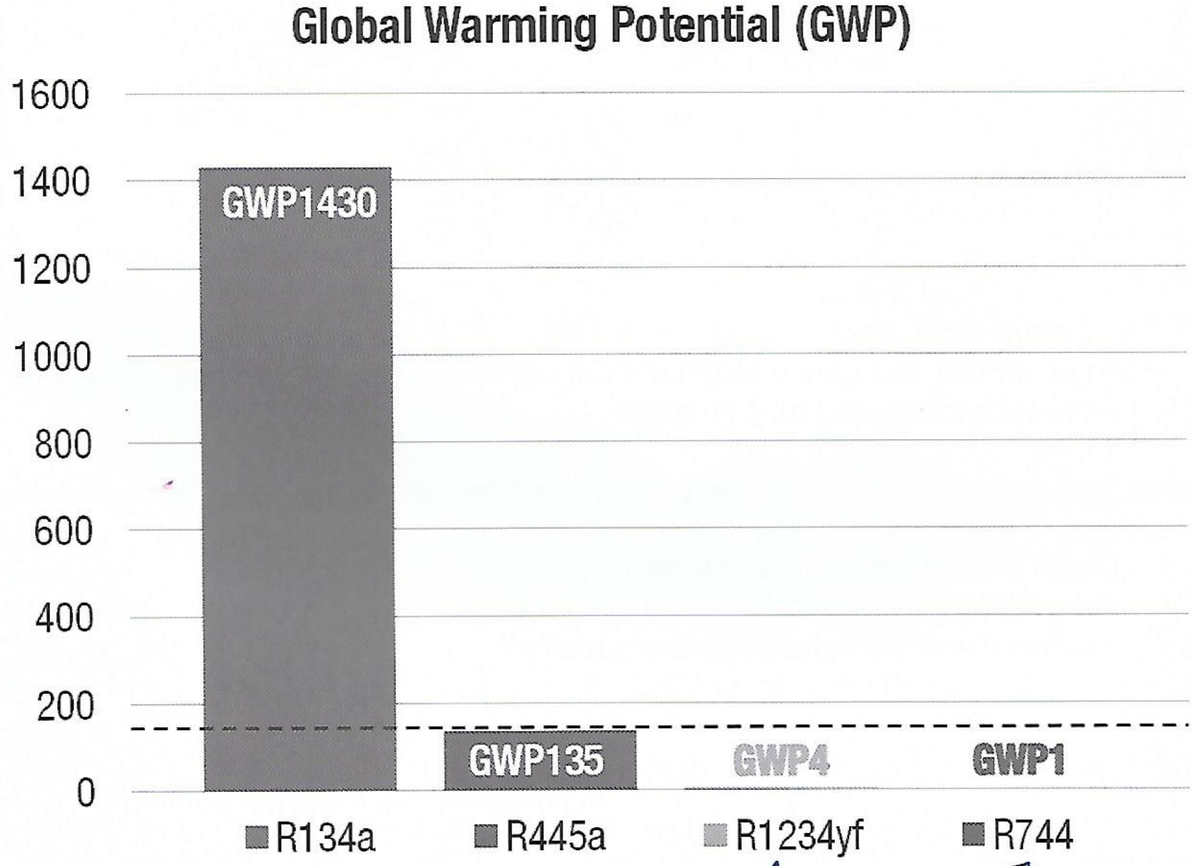
REFRIGERANT TYPES continued...

R445a

Refrigerant R445a also known as AC6 was an option being investigated by the Renault-Nissan Alliance. Like R1234yf, it performs very similarly to R134a. However, with a GWP of 135 it is only just below the 2017 limit and has a high risk of being incompatible with future reductions in the GWP. Renault-Nissan argue that there are issues with R1234yf that are yet to be overcome *(see: The R1234yf Controversy).* and that the technology does not yet exist for R744 to operate efficiently. At the time of writing this training manual all evidence is suggesting that the Renault-Nissan Alliance have abandoned the development of R445a as new models in Europe are using R1234yf.

Global Warming Potential (GWP)

The following graph compares Global Warming Potential (GWP) values for the current refrigerant options:



Flamable.

CO_2

REFRIGERANT TYPES continued...

Comparison
The following table compares the different properties for the current refrigerant options:

	R1234yf	R744	R445a
Poisonous	No	No	No
Flammability	Conditional	No	No
Cost	High	Low	Moderate
Pressure	Moderate	Very High	Moderate
Performance	Good	Average	Good
Architecture	Existing	New	Existing
GWP Rating	4	1	135
Serviceability	Good	Poor	Average

Note: *R134a – R1234yf – R744 – R445a*

All 4 are incompatible with each other and all have their own specific lubricants.

The R1234yf Controversy
During crash testing of new model vehicles using R1234yf Mercedes Benz claim that they have proof that under the correct circumstances that the new refrigerant becomes flammable. After a long battle with the European Union Mercedes Benz dropped its protest and conceded that it will use R1234yf in all systems until a time when R744 technology can take its place

Along with other manufacturers the following reasons are being given for finding an alternative to R1234yf:

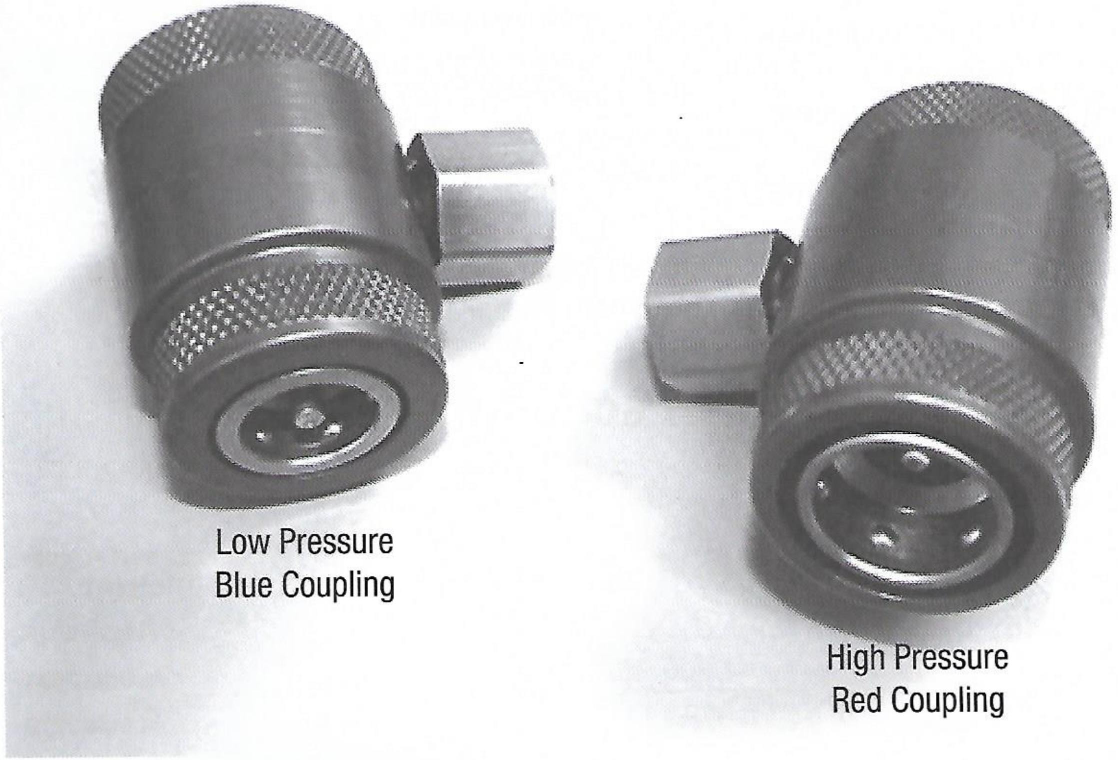
- Crash testing shows potential for flammability
- Patent jointly owned by DuPont-Honeywell, this ties the entire industry to two suppliers
- Cost is about 10 times that of R134a
- Not the best environmental option

As a countermeasure to their flammability claim,Mercedes Benz are fitting a canister of inert Argon gas under the hood of all R1234yf models. If the vehicle is in an incident that deploys an airbag the Argon gas is released in the vicinity of the exhaust manifold preventing possible ignition of the refrigerant.

REFRIGERANT TYPES continued...

Service Couplings

To avoid incorrect servicing the service ports have been reduced in size slightly preventing the R134a quick release couplings from being connected.


Low Pressure
Blue Coupling
High Pressure
Red Coupling

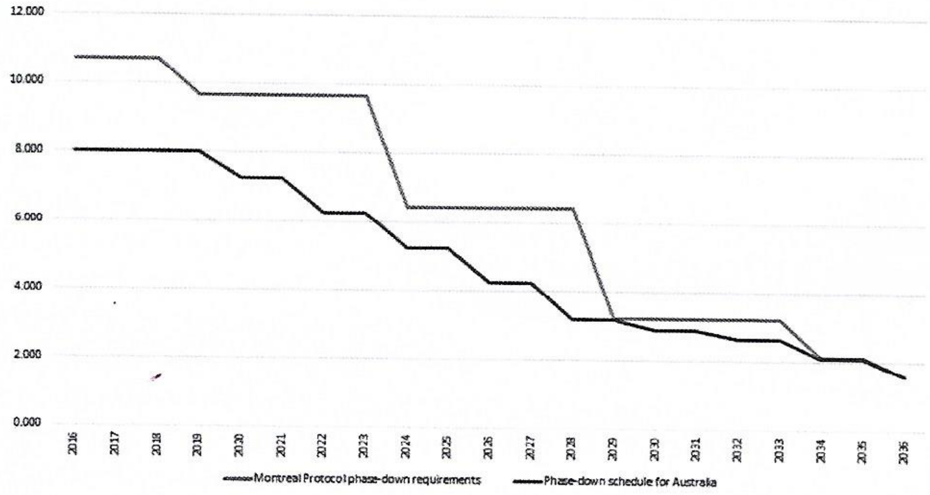
REFRIGERANT TYPES continued...

Australian OPSGG Program

- Ozone Protection & Synthetic Greenhouse Gas Program
- It is our commitment to the Montreal Protocol
- Came into effect 1st January 2018
- Places limits on new products containing HFC's (inc. R134a) R1234yf in an HFO
- Includes both local production and imported products
- Phase-down not phase-out of HFC's
- R134a will not be banned, it will always be available for servicing

The following graph shows the requirement under the Montreal Protocol in grey (upper line) and Australia's OPSGG Program in black (lower line). The Australian Government have taken a larger initial reduction and will then take many more smaller steps before finalising the agreement on par from 2034.

HFC phase-down schedule



Montreal Protocol Reductions:

- 10% from 2019
- 40% from 2024
- 70% from 2029
- 80% from 2034
- 85% from 2036

Unlike the European legislation, Australia does not ban the use of R134a. It instead reduces the number of products containing HFC's each year. The legislation also gives the authorities the ability to enforce the switch to non-HFC's if the manufacturers can not prove that they are in the process of switching away from HFC's.

This is forcing Automotive manufacturers to start sending R1234yf vehicles to Australia from now on...

REFRIGERANT TYPES continued...

R1234yf in Australia

- Currently in Australia we have many imported vehicles that are running R134a, where they are running R1234yf in other markets
- Vehicles are using the same components for both gases
- R134a is a lot cheaper and a little better at cooling
- The Australian Government will now be able to fine or block imports to vehicle manufacturers that do not show progress of transfer to low GWP gases
- We will now start to see a greater number of vehicles entering the Australian market using R1234yf

Honeywell
Solstice™ yf Refrigerant

Dyes & Oils must be compatable with R1234YF

R1234yf SYSTEMS

Servicing R1234yf systems

- No licences are required to work with or purchase R1234yf
- All equipment working with R1234yf must meet SAE J2913
- Many R134a machines built after 2011 have been made compliant with J2913 and can be upgraded
- Nothing changes as far as service procedure is concerned
- Gas is very expensive, do not risk wasting any

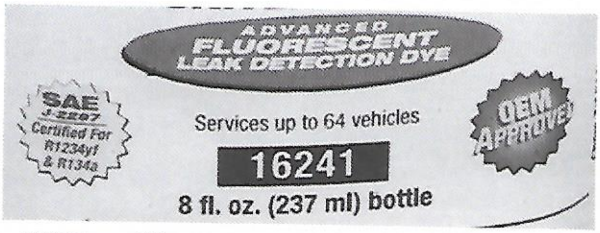
Most manufacturers that are producing vehicles with the same components that use both R134a and R1234yf show only very minor changes.

Oil Type

While most R1234yf systems use PAG oil it is a special blend and therefore has a special yf suffix (eg. PAG46yf). Hybrid vehicles using R1234yf use POE oils.

Fluorescent Dyes

While many oils come premixed with leak tracing dyes there are occasions when a dye needs to be added while the system is in service.
Dyes that comply with SAE J2297 are suitable for both R1234yf and R134a, but check the label of any dye to confirm as older products may not be compliant.


ADVANCED FLUORESCENT LEAK DETECTION DYE
SAE J-2297 Certified For R1234yf & R134a
Services up to 64 vehicles
16241
8 fl. oz. (237 ml) bottle
OEM APPROVED

J2297 certification displayed in lower left corner

Charge Quantity

Typically the charge quantity for R1234yf is slightly lower, manufacturers specifications seem to vary anywhere from the same charge as R134a to 15% less

SYNC
Mastercool

R1234yf SYSTEMS continued...

Pressures

Low-side pressures for R1234yf are anywhere from the same as R134a up to 20% higher

High-side pressures for R1234yf are anywhere from the same as R134a up to 10% lower

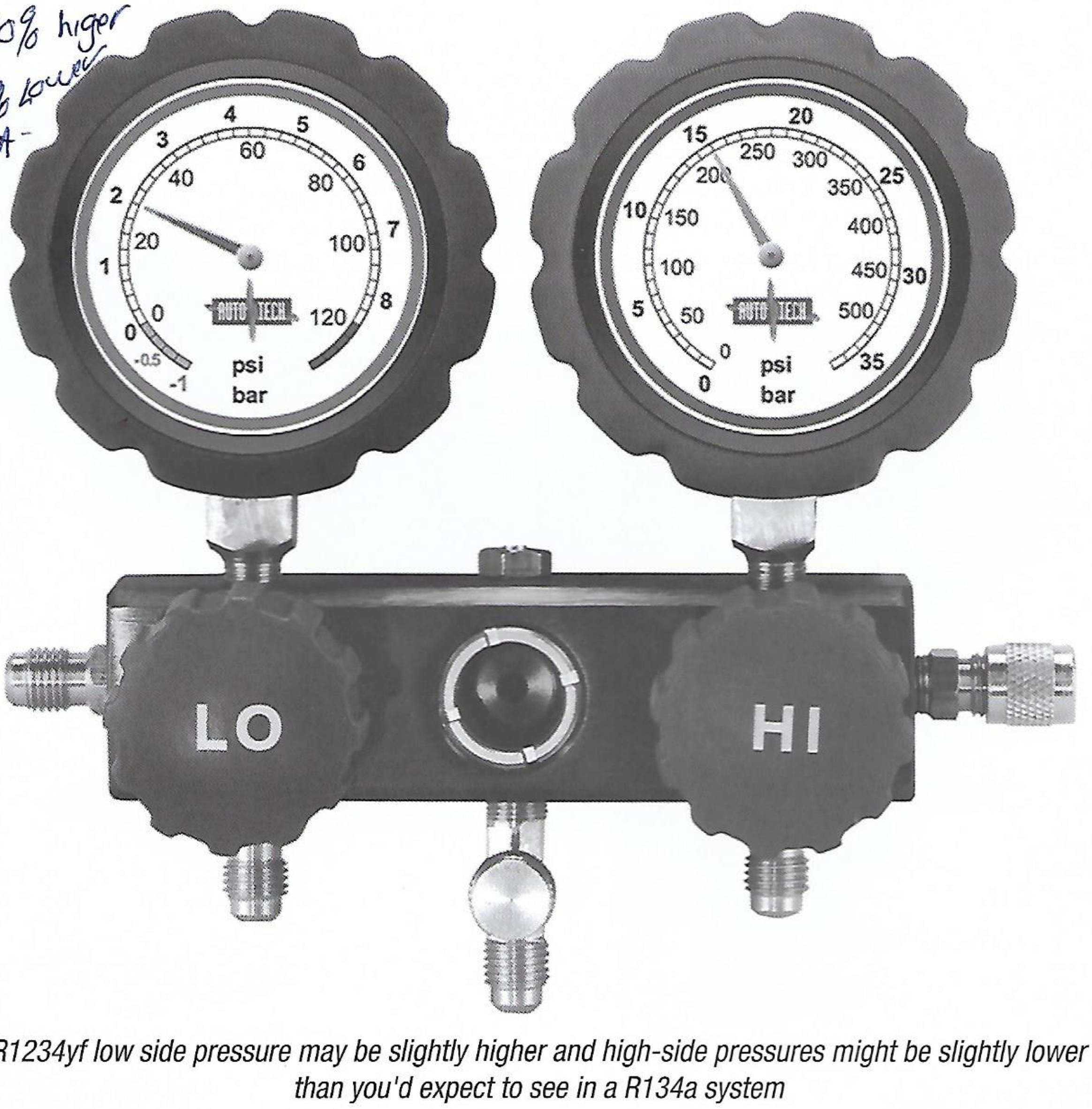
Most vehicles are currently being built with the ability to use R1234yf. Because the gas is slightly less efficient than R134a the changes to the system include:

- Higher efficiency condenser
- Higher efficiency evaporator
- Utilising an Internal Heat Exchanger (IHX)

Depending on the manufacturers requirements they may employ some or all of these modifications. Increasing the efficiency of the Condenser or the Evaporator simply means increasing the surface area of the tubes and this can be done by moving them closer together or simply adding more.

Low side 20% higer

High side 10% lower
than R134A-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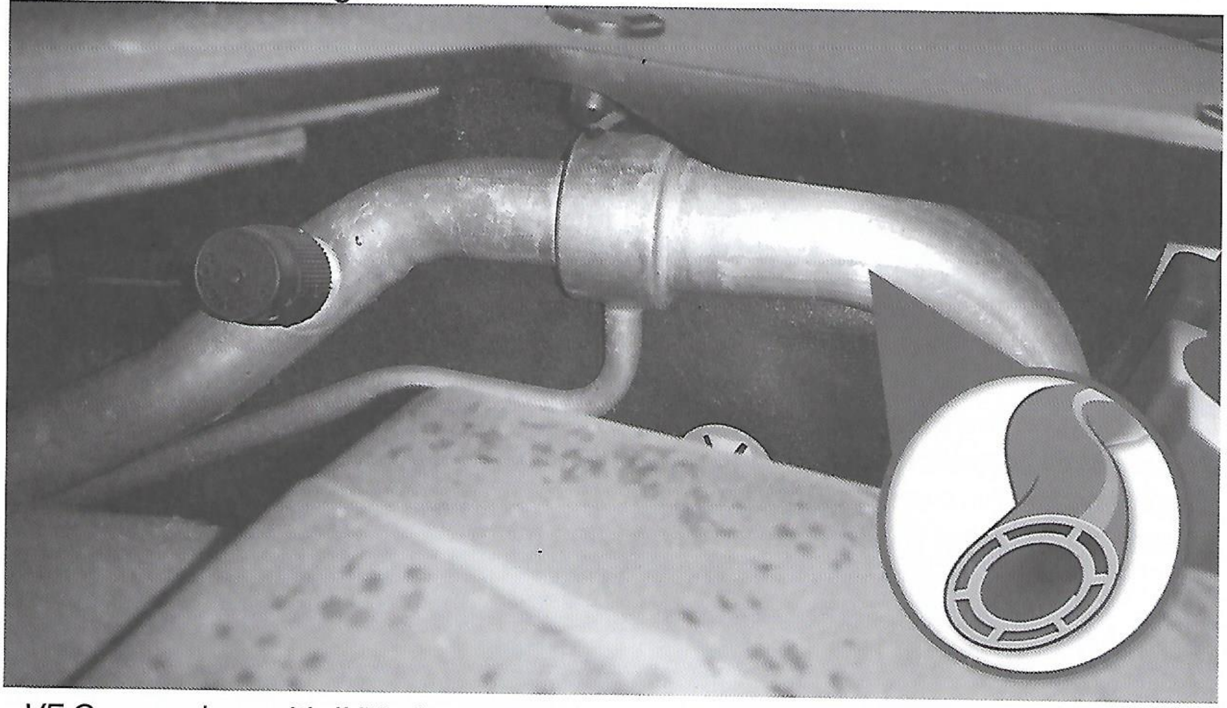
R1234yf low side pressure may be slightly higher and high-side pressures might be slightly lower than you'd expect to see in a R134a system

R1234yf SYSTEMS continued...

Internal Heat Exchanger

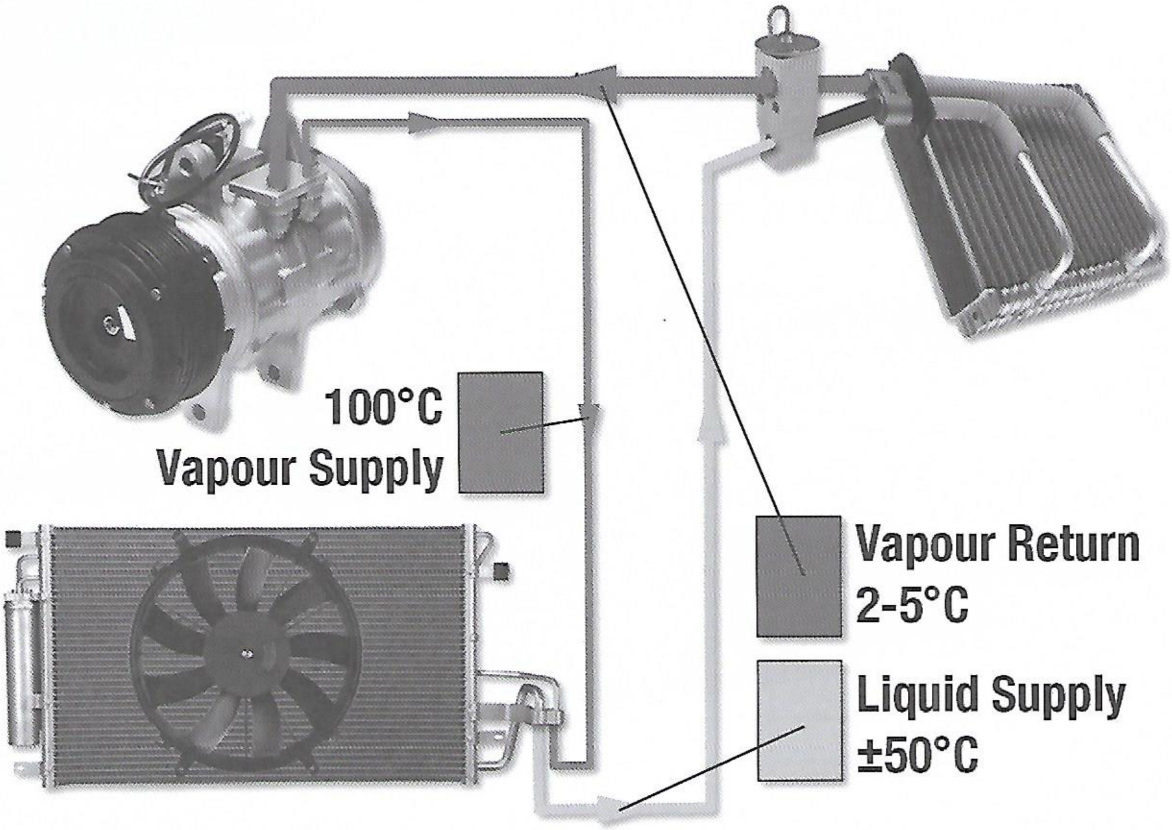


VF Commodore with IHX - insert showing internal structure of the heat exchanger

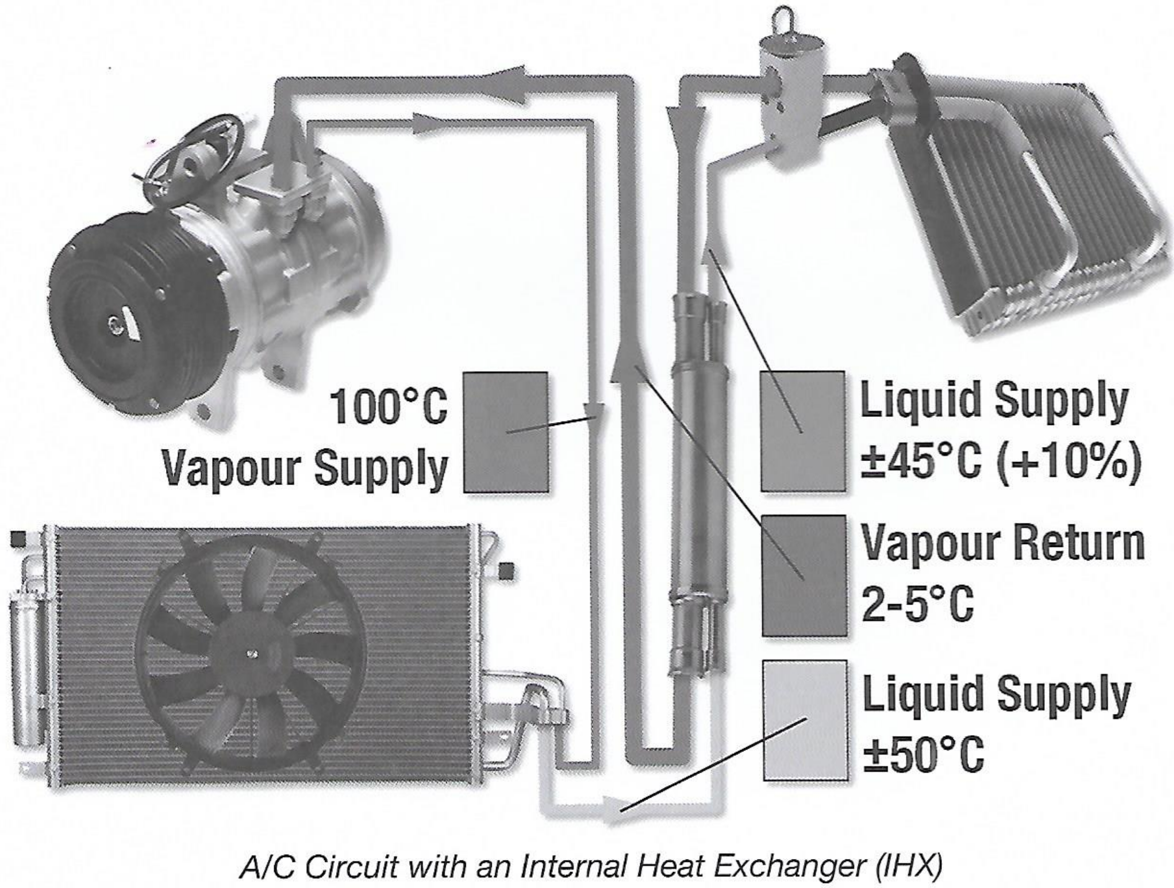
The theory is simple; cold gas exiting the evaporator is wasted and is usually at between 2°C and 5°C. By running the previously considered wasted cold gas refrigerant through a heat exchanger with the liquid refrigerant fresh from the condenser a temperature drop of about 5°C (equivalent to a 10% gain) can be achieved before entering the Thermal Expansion (Tx) Valve.

The images on the following page illustrate the system layout:

R1234yf SYSTEMS continued...


100°C
Vapour Supply
Vapour Return
2-5°C
Liquid Supply
±50°C

Traditional A/C Circuit


100°C
Vapour Supply
Liquid Supply
±45°C (+10%)
Vapour Return
2-5°C
Liquid Supply
±50°C

A/C Circuit with an Internal Heat Exchanger (IHX)

R744 SYSTEMS

- Mercedes Benz S400 Coupe MY17 first production vehicle
- Will spread to entire S-Class then E-Class range
- For EU domestic sales only
- High-side pressure up to 2000 psi (130 bar)
- VAG (Volkswagen Group) currently testing R744
- Unsure if R744 will ever be suitable for AU climate with current technology

SPECIAL SERVICE TOOLS

Name	Part Number
Gauge Set (R134a)	TOX9351
Gauge Set (1234yf)	TOX1027
Recovery Station w/oil seperator (R134a / R1234yf)	MINIMAX-RA
Recovery Station (R134a / R1234yf)	EQX69400
Charging Scales	TOX8200
	TOX8315
Manual Charging Station (R134a / R1234yf)	EQX1586
Automatic Charging Station (R134a)	ACM3000ROB-AU
	EQX2000
	34988I
Automatic Charging Station + conversion kit (R1234yf)	AC1X34-3P + 1x34_3CONV
Automatic Charging Station (R1234yf)	EQX4000
A/C Refrigerant Identifier	CMAC039
Dye Leak Testing Kit	TOX216
	TOX9245
Infrared thermometer	RST195
Dash Vent Thermometer	TOX012
	TOX008
Thermal imaging camera	ET2027

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